Security Challenges in the era of Internet-of-Things and Deep Learning

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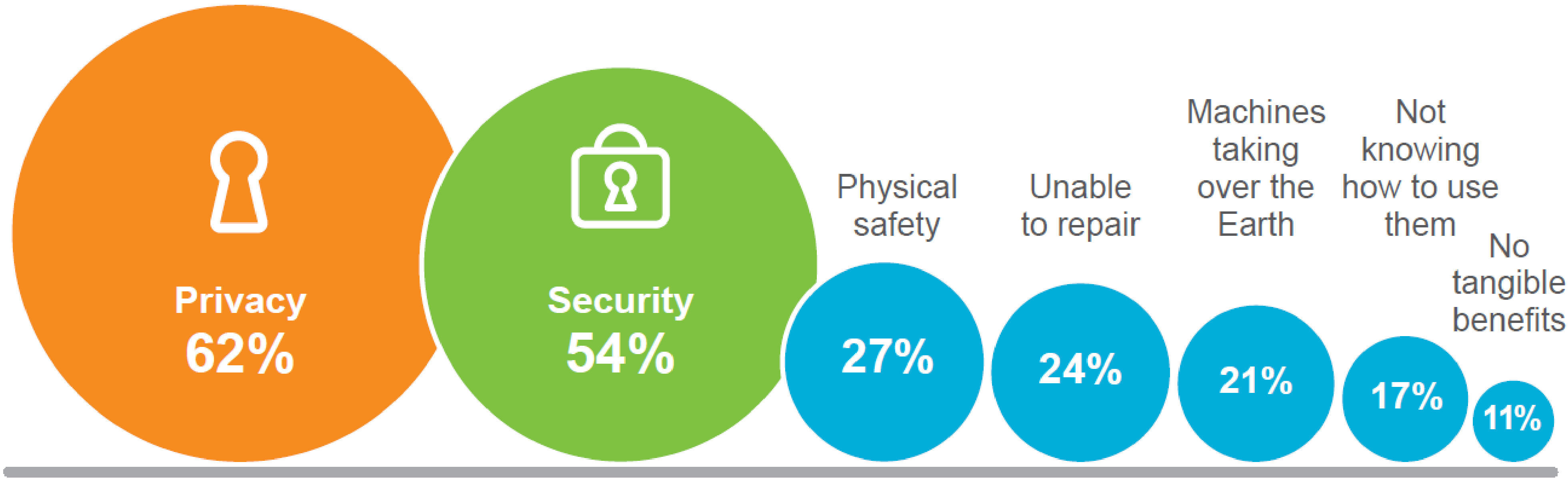
What concerns you about a world of connected IoT devices?



Results of a a global customer survey (2016) [1]

source: https://learn.sparkfun.com/tutorials

Limited resources

Evolved threat landscape

source: http://gizmodo.com/

What defines IoT securtiy?

New trust models

source: https://thenounproject.com/term/handshake/6020

Increased privacy concerns

source: http://www.dlink.com/se/sv/products/

source [2]

New trust models

source: http://www.littleindia.se


source: http://sdxcentral.com

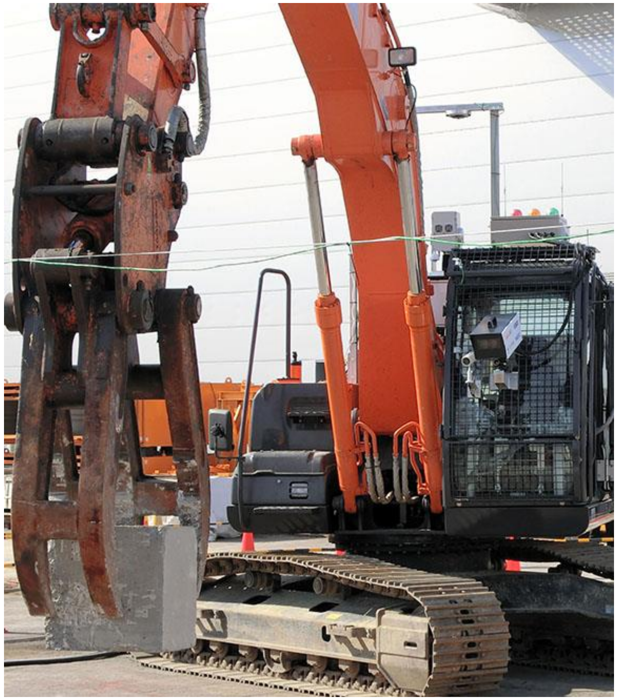
Access and interconnect networks may not be trustworthy

- Access network may be operated by a shopping mall, a coffee shop, etc.
- 3rd parties may access to interconnect network, e.g., for analysis

Intermediaries on which IoT systems rely may not be trustworthy

- IoT devices which mostly sleep rely on proxies to cache requests and responses
- In mesh networks, every node is an intermediary

Increased privacy concerns



source: http://www.asahi.com

- Big data generated in IoT opens great opportunities for analytics, automation, and process and resource optimization
- But it also increases the risk of privacy breaches

Secret surveillance of Norway's leaders detected

Members of parliament and the prime minister of Norway are being monitored by means of secret espionage equipment.

SECURITY

Hacker looks to sell 9.3 million alleged patient healthcare records on the dark web

By James Rogers
Published June 28, 2016
FoxNews.com

Evolved threat landscape

source: http://www.dqindia.com/cognizant-is-betting-big-on-connected-cars/

- Increased attack surface
- Increased value for attackers
- Decreased cost of performing attacks
- Increased damage when attack happen

source: http://www.one7group.com/english/portfolio/graphic_design/oil_company.html

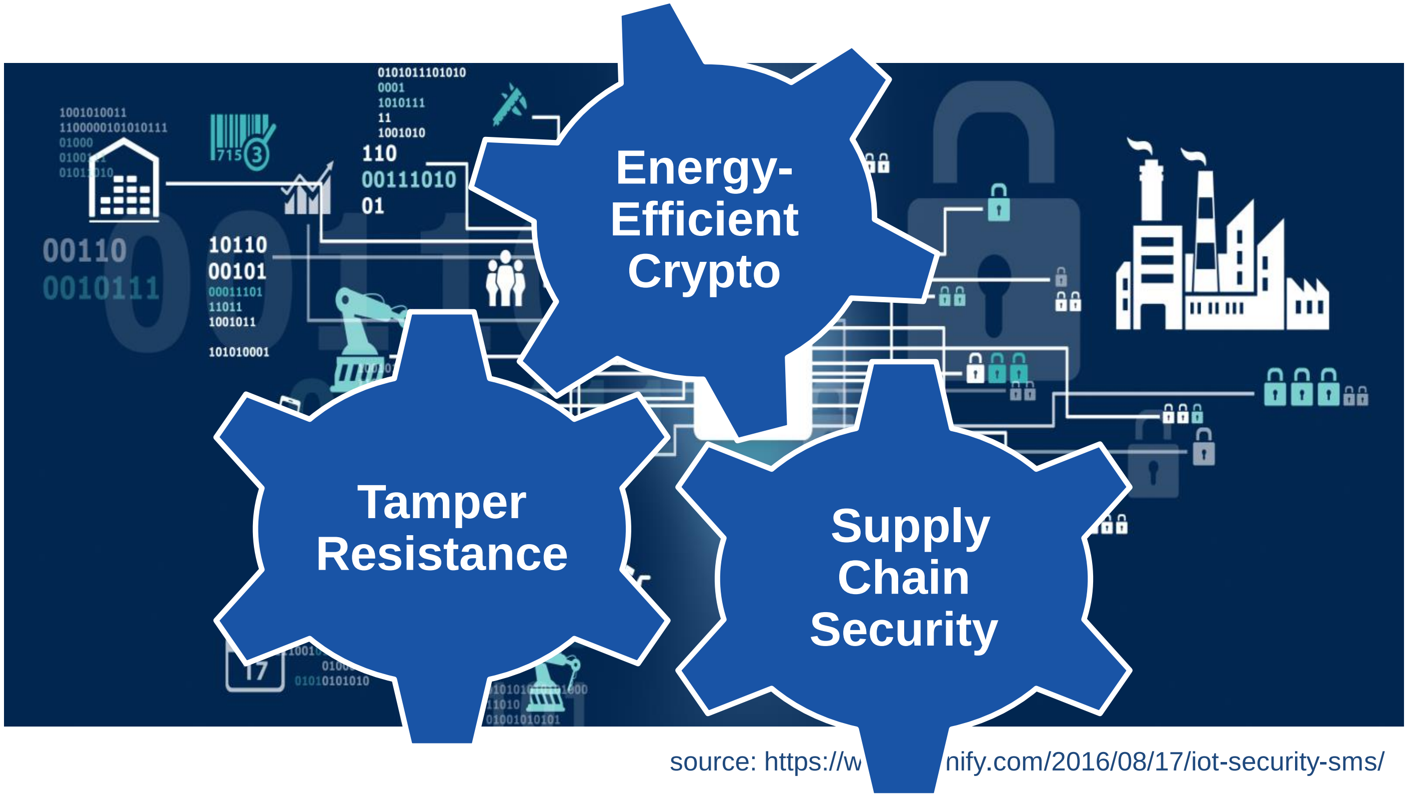
source: https://keranews.org

source: https://blog.econocom.com/en/blog/smartbuilding-and-bms-a-little-glossary/

Limited resources

- IoT devices with limited computing, storage, and communication resources may not be able to afford standard cryptographic algorithms and protocols
- Battery-operated IoT devices need to be energy efficient to prolong their lifetime
- Ensuring robust over-the-air firmware and software updates is crucial, but challenging when:
  - there is not enough memory to save both old and new updates
  - applications are infected by viruses blocking the updates

How to assure IoT devices?

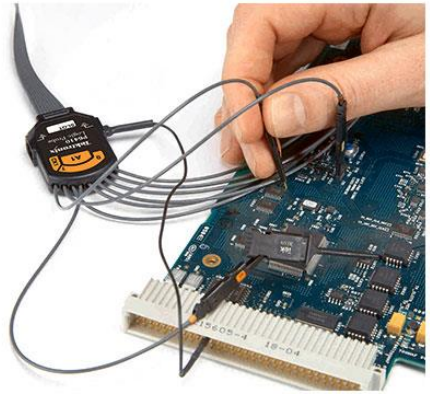


source: https://w nify.com/2016/08/17/iot-security-sms/

Assuring Tamper Resistance

Why tampering?

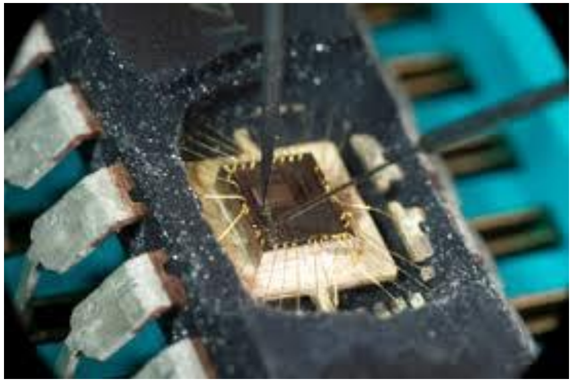
source: www.clearwater-fl.com



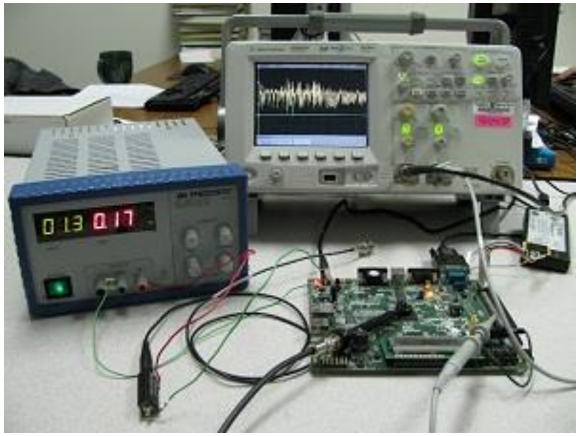
source: www.tek.com

- Theft of service
  - Getting a service for free
    - pay-TV, parking cards, electricity meters, …
- Denial of service
  - Dishonest competition
- Theft of Intellectual Property (IP)
  - Reverse engineering/cloning/counterfeiting for marketplace advantage
- Theft of sensitive data/personal information
  - Steal the secret key

How to tamper?



source: sec.ei.tum.de



source: hackaday.com

- Invasively intrude a chip/board
- Measure side-channel signals, e.g. power consumption, EM emissions, timing
- Inject faults to corrupt the computation and exploit the effect

Traditional key storage methods

- Fuses
- Non-volatile memories (Flash, EEPROM, …)
- Volatile memories (SRAM) with a battery

- Problem with memory-based storage
  - Residuals of data may remain after erasure
    - data remanence

Data remanence in volatile memories

Volatile memories (SRAM, DRAM) do not entirely lose their contents when power is turned off

- for SRAM, at room temperature the data retention time varies from 0.1 to 10 sec
- cooling SRAM to -20ºC increases the retention time to 1 sec to 17 min
- at -50ºC the retention time is 10 sec to 10 hours

source: revision3.com

“Physical Attacks on Tamper Resistance: Progress and Lessons”, S. Skorobogatov, Special Workshop on HW Assurance, 2011

Novel key storage method:
Physical Unclonable Functions (PUFs)

- Due to manufacturing process variations, every chip is slightly different
- We can use these differences to create a unique “fingerprint” for each chip

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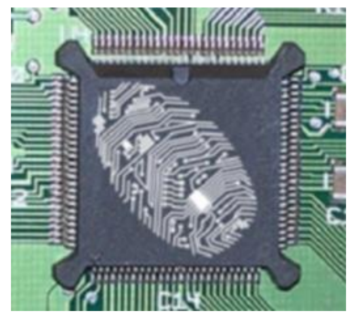
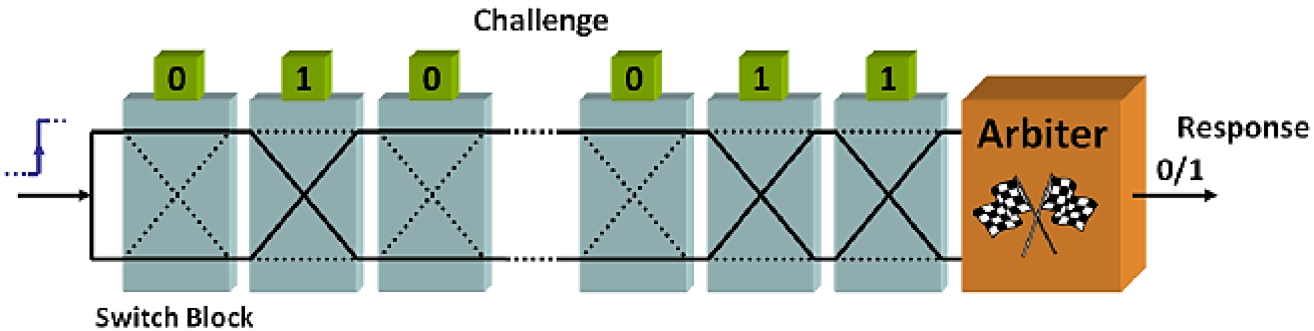
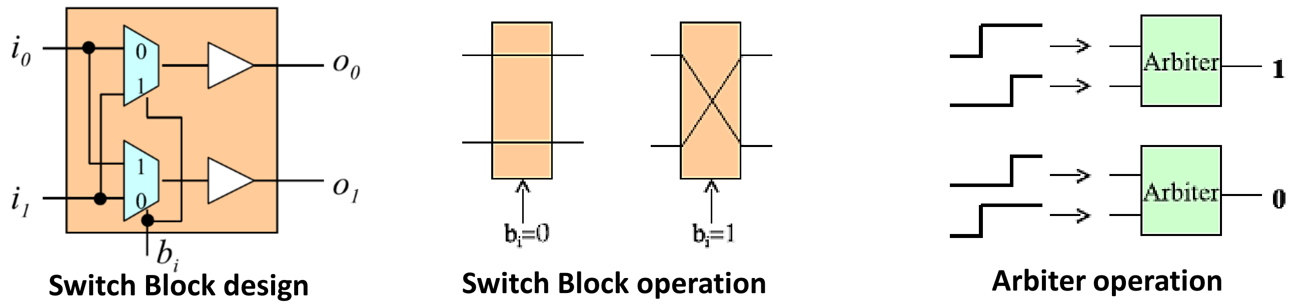


Arbiter PUF

Creates a race between two identical paths

- process variations cause small differences in delays





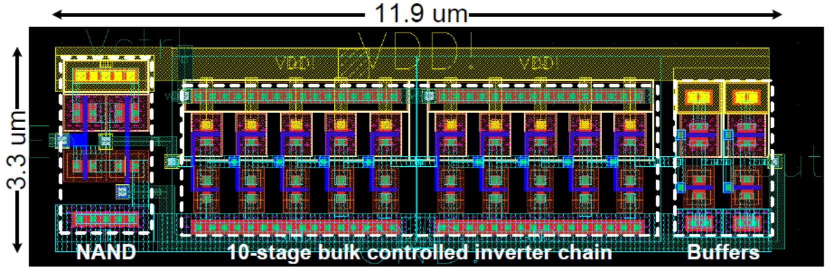
Advantages of PUF-based key storage

	PUF	TRNG + Memory	External Key Injection
Key Generated on-chip	✓	✓	✗
No Secure Storage Needed	✓	✗	✗
Key Invisible at Power Off	✓	✗	✗

PUF research at KTH

We design PUFs which are among the best in the state-of-the-art in terms of energy efficiency and reliability

“Temperature Aware Phase/Frequency Detector-Based RO-PUFs Exploiting Bulk-Controlled Oscillators”, S. Tao, E. Dubrova, DATE'2017, March 27-31

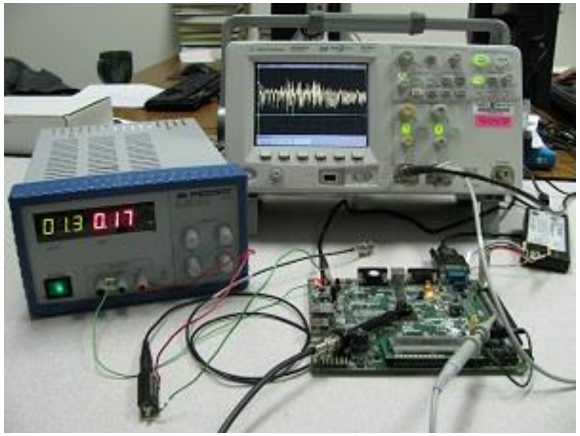


Side-channel attacks

- Side-channel signals are related to the data processed
  - e.g. different amount of power is consumed

- Do not require expensive equipment

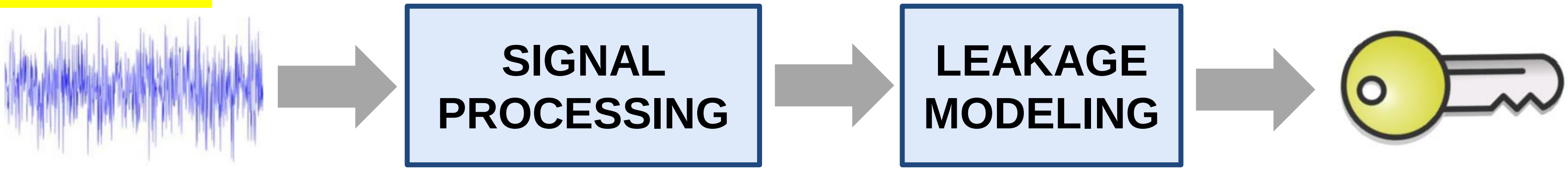
- Deep Learning (DL) makes possible a new type of side-channel attacks



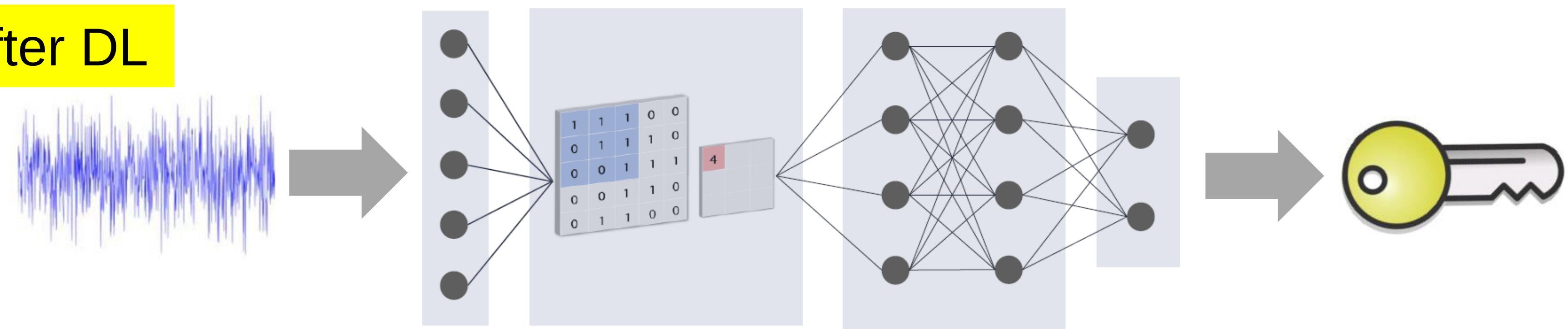
source: hackaday.com

Side-channel attacks before and after DL

Before DL



After DL

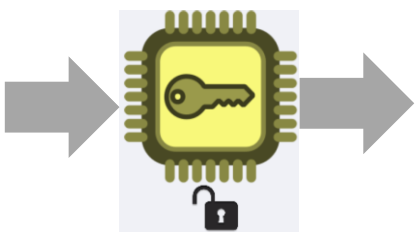


source: riscure.com

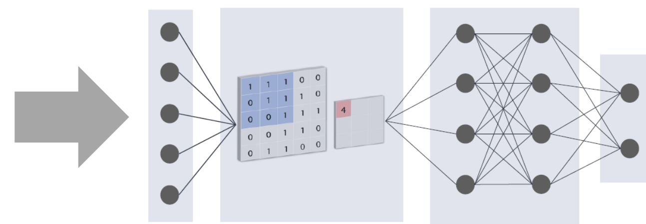
DL-based side-channel attack - Profiling stage

2. Create traning/validation labeled data sets

1. Apply random plaintext & keys



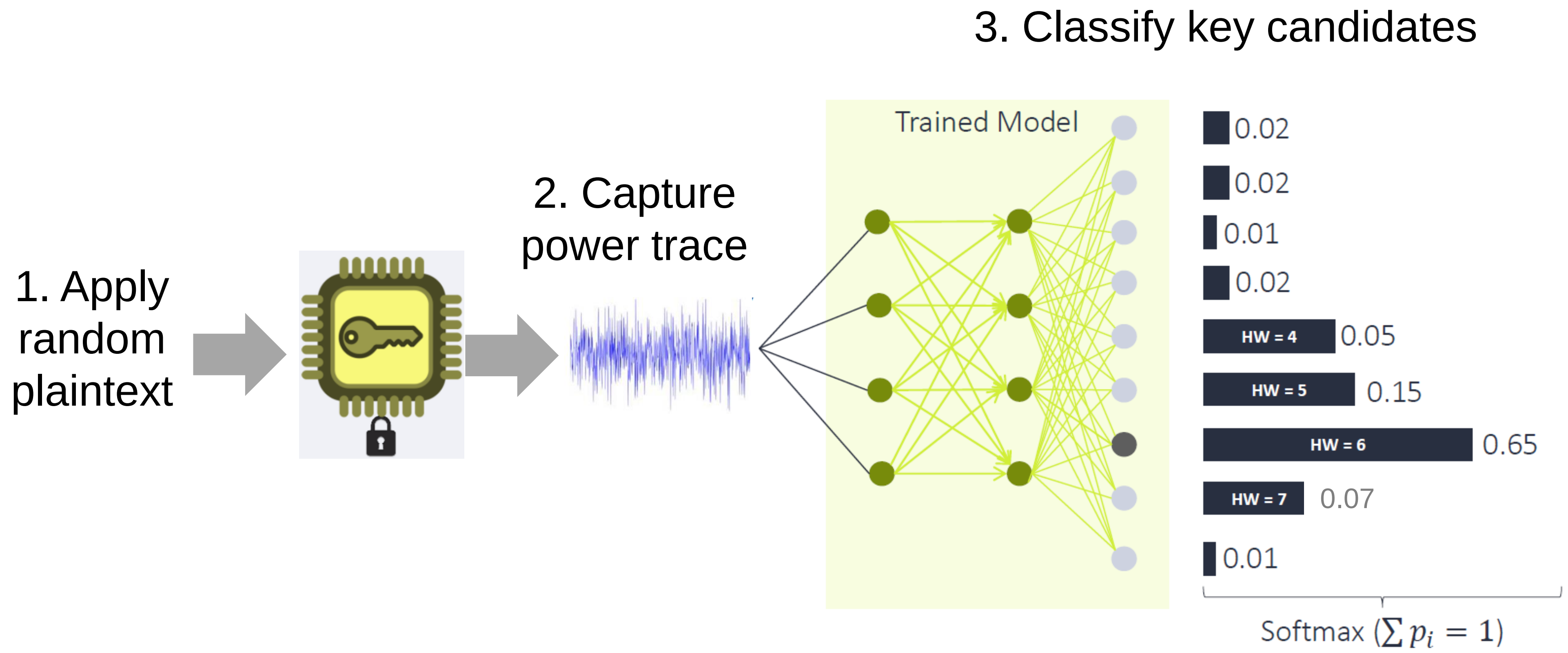
3. Train neural network



source: riscure.com

Leakage model

DL-based side-channel attack – Attack stage



source: riscure.com

Side-channel attack research at KTH

- Attack on USIM card using power consumption
- Attack on a Bluetooth device using EM far filed emissions
- Attack on a protected arbiter PUF implemented in FPGA using power consumption combined with bitstream modification

USIM attack

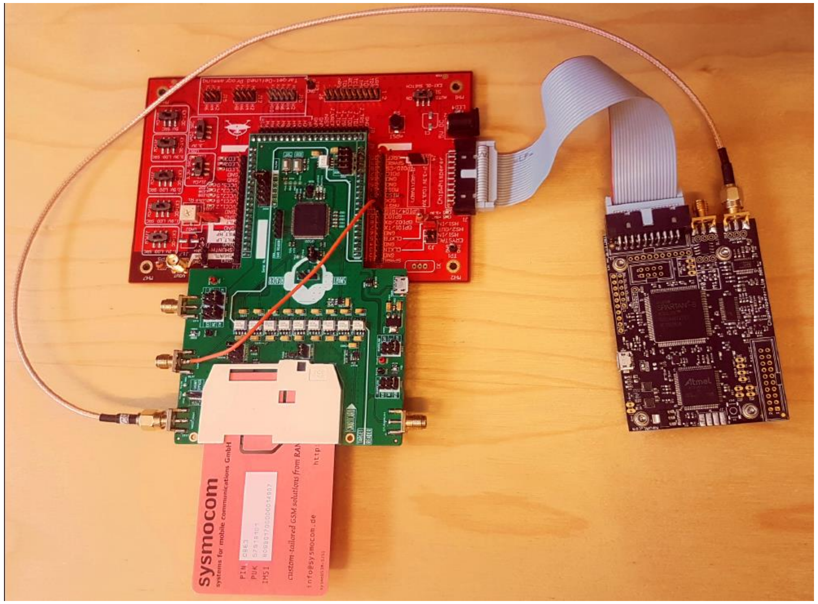
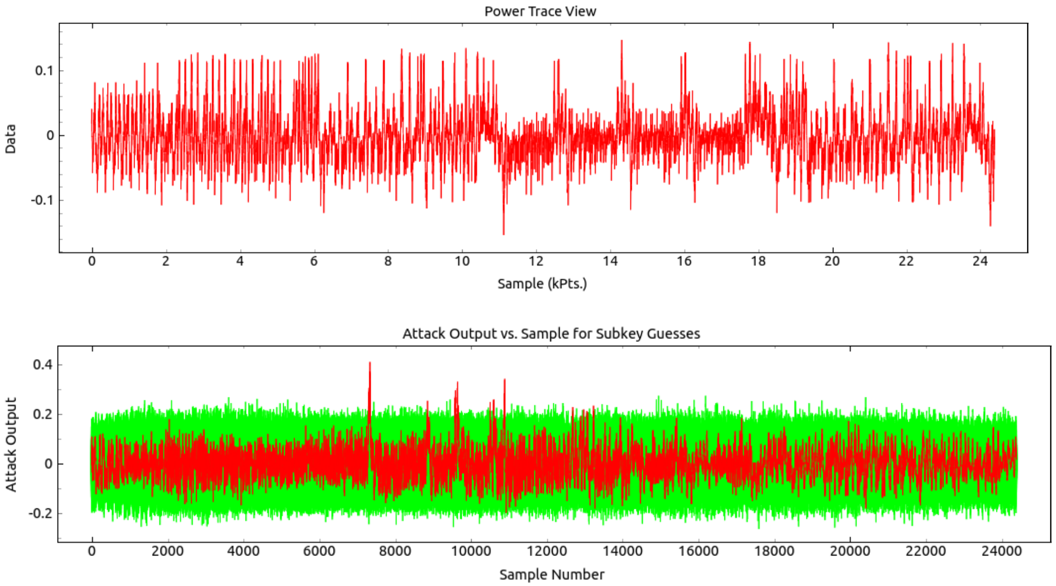


photo credit: Martin Brisfors



The secret key can be extracted from USIM using 4 power traces on average (20 in the worst case) [3]

Bluetooth device attack

photo credit: Katerina Gurova

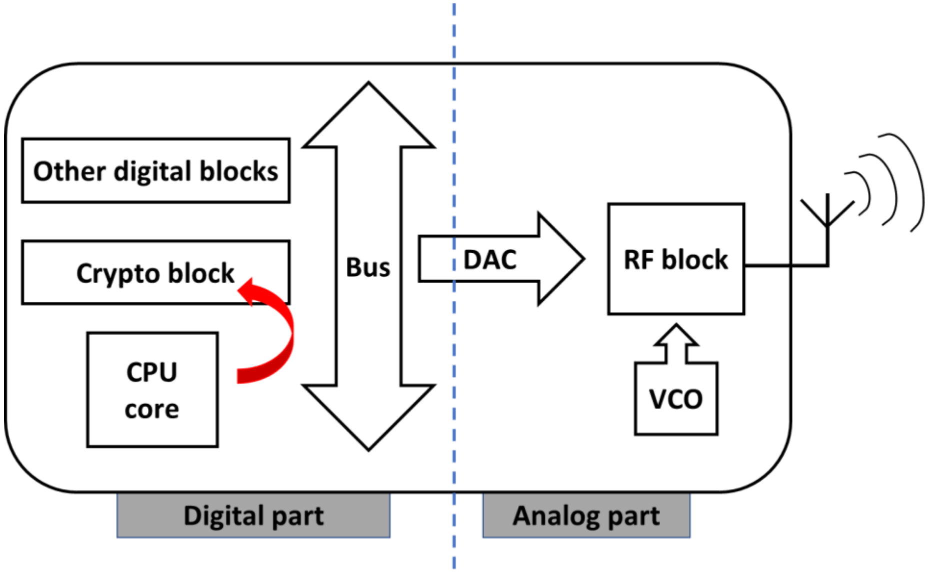
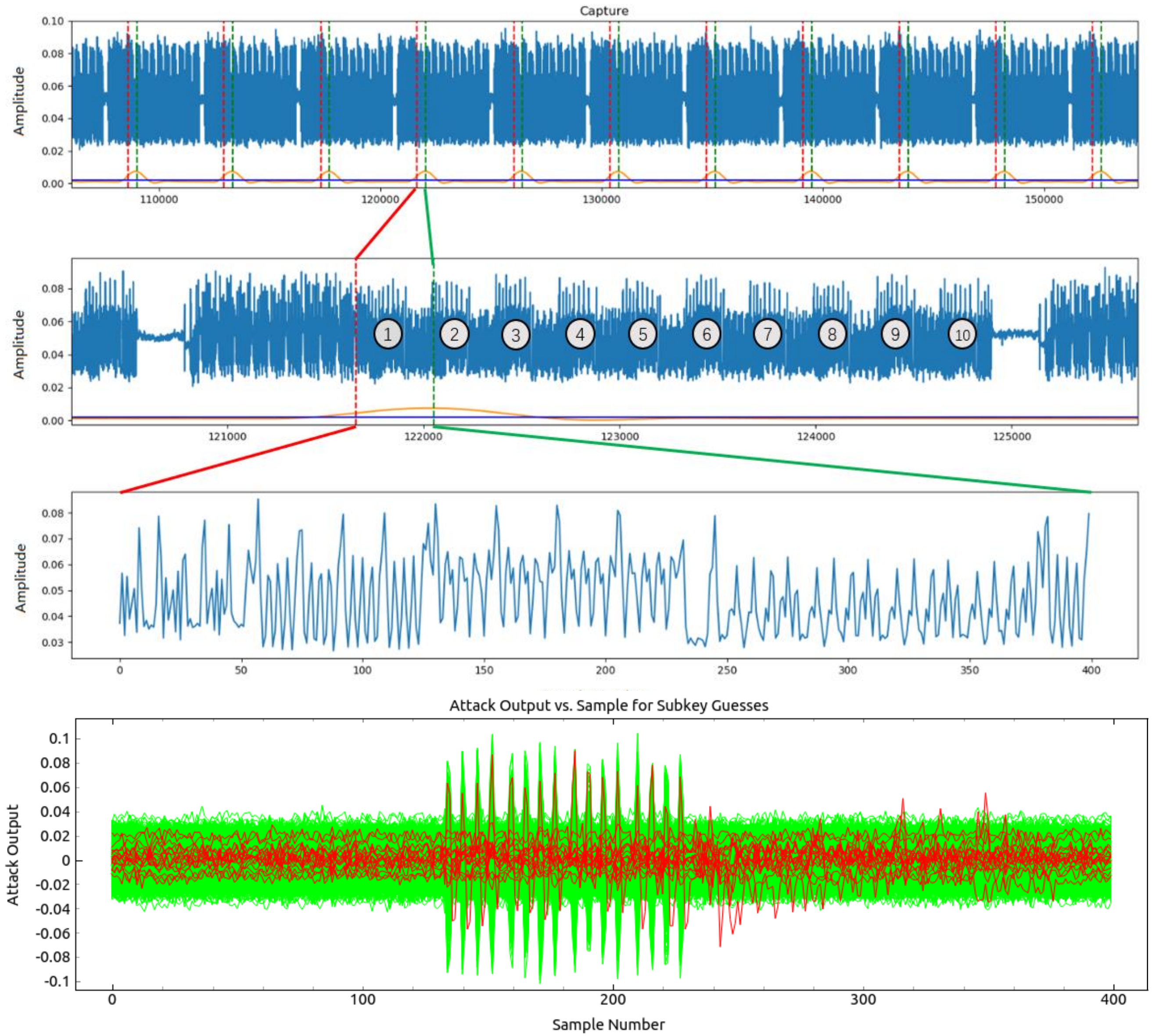


photo credit: Katerina Gurova

The AES encryption key can be extracted from a Bluetooth device (Nordic Semiconductor nRF52 DK) from 10K EM traces captured at 15 m distance [4]


Capture
Amplitude
1
2
3
4
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9
10
Attack Output vs. Sample for Subkey Guesses
Attack Output
Sample Number

PUF attack

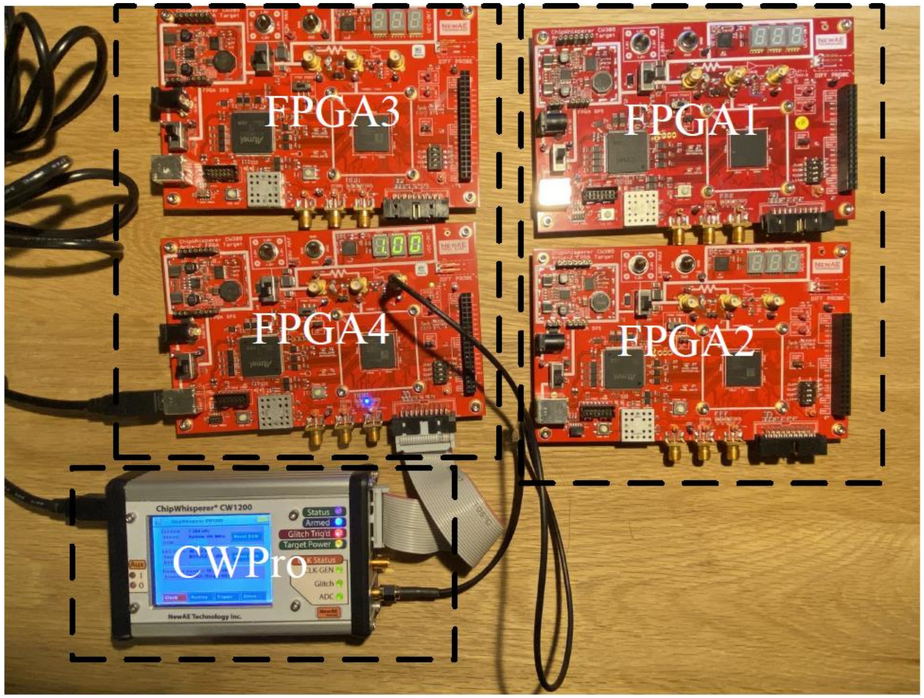

photo credit: Yang Yu

Responses of a protected arbiter PUF can be extracted from its FPGA implementation (Xilinx 28 nm Artix 7) using power traces [5]

Summary and future work

- Needs for tamper-resistance of IoT devices grow due to
  - physical accessibility
  - increased value of stored/processed information
- Difficulty to assure tamper-resistance also grows due to
  - constrained resources
  - recent progress in physical attacks
  - lack of protection
- We need to understand possibilities and limitations of physical attacks making use of DL and develop defenses

References

[1] Mobile Ecosystem Forum, *The Impact of Trust on IoT*, http://mobileecosystemforum.com/initiatives/analytics/iot-report-2016

[2] *IoT Security*, Ericsson White paper, 2017

[3] *How deep learning helps compromising USIM*, M. Brisfors, S. Forsmark, E. Dubrova, IACR Cryptology ePrint Archive, 2020

[4] *Far filed side-channel attack on AES using deep learning*, R. Wang, H. Wang, E. Dubrova, ACM Workshop on Attacks and Solutions in Hardware Security, ASHES'2020, Nov 9-13, 2020, Orlando, USA

[5] *Profiled deep learning side-channel attack on a protected arbiter PUF combined with bitstream modification*, Y. Yu, M. Moraitis, E. Dubrova, IACR Cryptology ePrint Archive, 2020/1031