Hardware-entangled security

Extracting a secure key from IoT hardware

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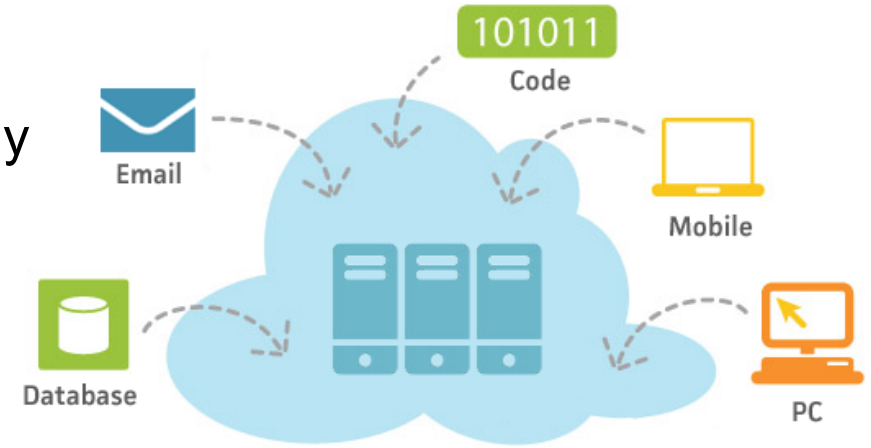
Cloud components and security

- Different components: Services, devices, databases, raw code, software applications, firmware….
- Which components can/should be really considered as secure?
- Where is the user??
- Why do we assume that security established by/from the user (credentials) is equal to a secure computer?

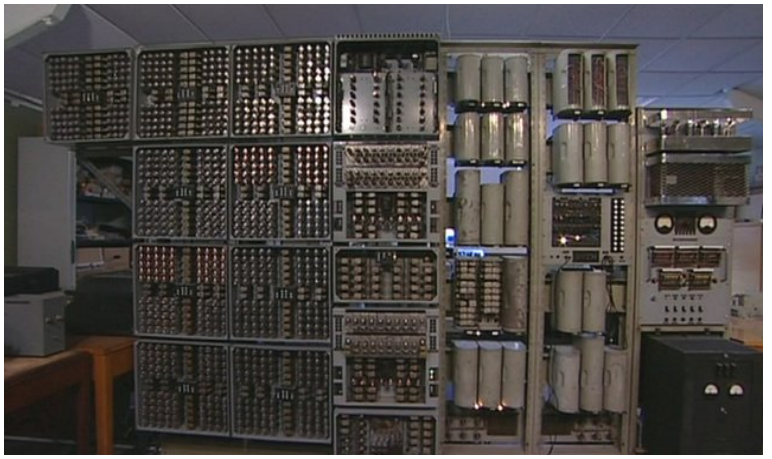


Insecurity in the cloud

- Not all services on the cloud can be considered secure.
- However, users and companies need the cloud because of its availability, flexibility, scalability, ease of service, ….
- Is there a solution?
- If photographs are not safe on the cloud, would you risk your business data?

Hardware-entangled cryptography

- Can we bind services to hardware?
- Hardware will always be present when accessing the cloud.
- However, there may be convenience issues.
- Nevertheless, browser-based services already do flexible binding.
- Advantages:
  - Much more difficult to break.
  - Can be combined with existing solutions.
  - Client-based flexibility.



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Project P3
Hardware-entangled cryptography

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Hardware-entangled cryptography

Physical(ly) Unclonable Functions

- Cryptography based on hardware characteristics
- Functions embedded into physical objects
- Can be used for identification, secure key storage or even in bit commitment and oblivious transfer schemes

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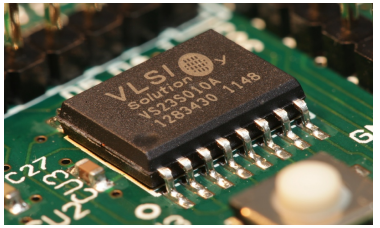
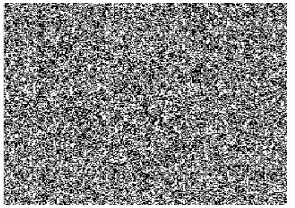
Use cases for PUFs

- Authentication and identification

- Integrity of devices
  - Anti-counterfeiting
  - Tamper-evidence

- Lightweight security





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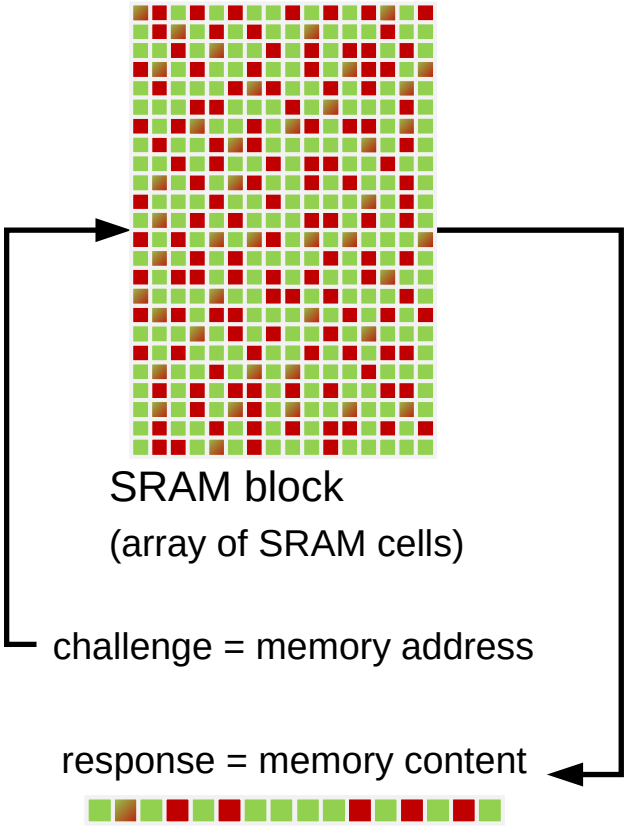
PUFs

Physical Unclonable Functions (PUFs)

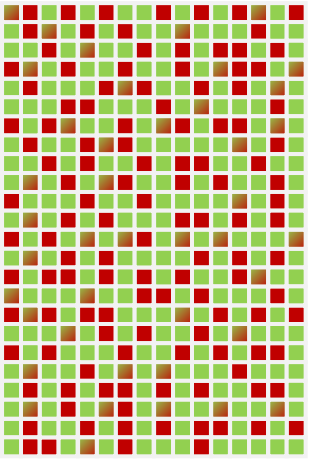
- Functions embedded into physical objects
- Manufacturing process variations
  → unique identity for ICs
- When queried with a challenge, a PUF generates a response (Challenge-Response Pair; CRP)
- The response depends on
  - the challenge **and**
  - specific physical properties of the object



Weak PUFs

Weak PUFs

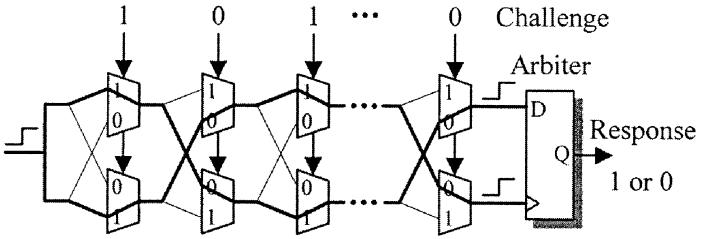
- A single or very few challenge-response pairs
- Memory-based PUFs
- In production stage
- Inherent to most devices

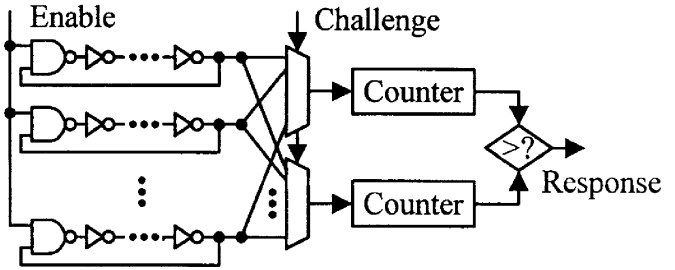


Strong PUFs

Strong PUFs

- Multiple challenge-response pairs
- Delay-based PUFs
- Still on the prototype stage
- Require dedicated circuitry

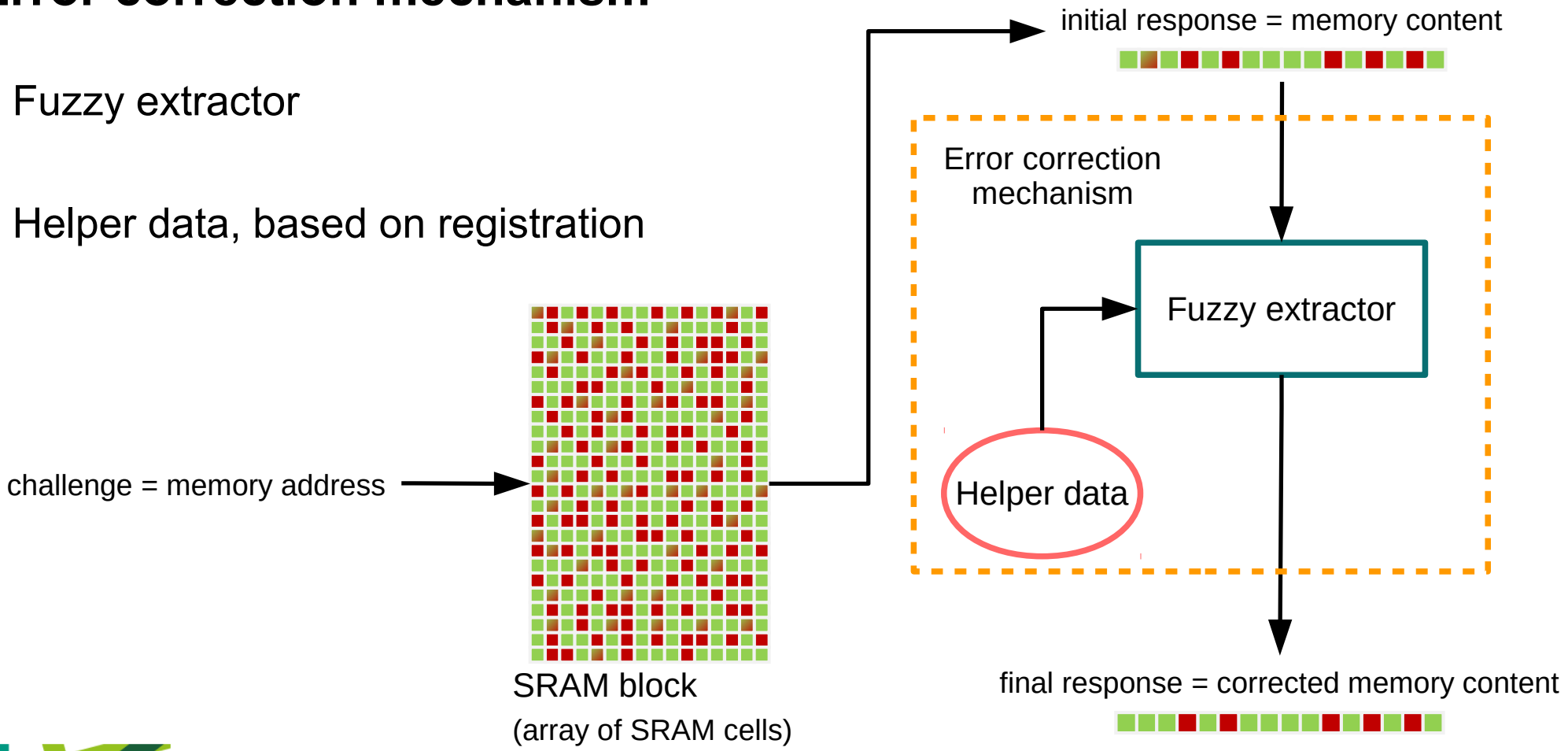




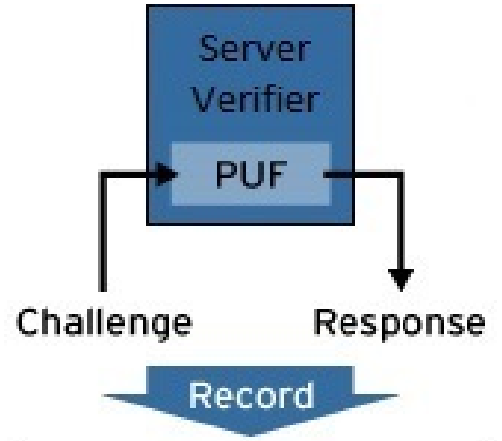
Error correction for PUFs

Error correction mechanism

- Fuzzy extractor
- Helper data, based on registration

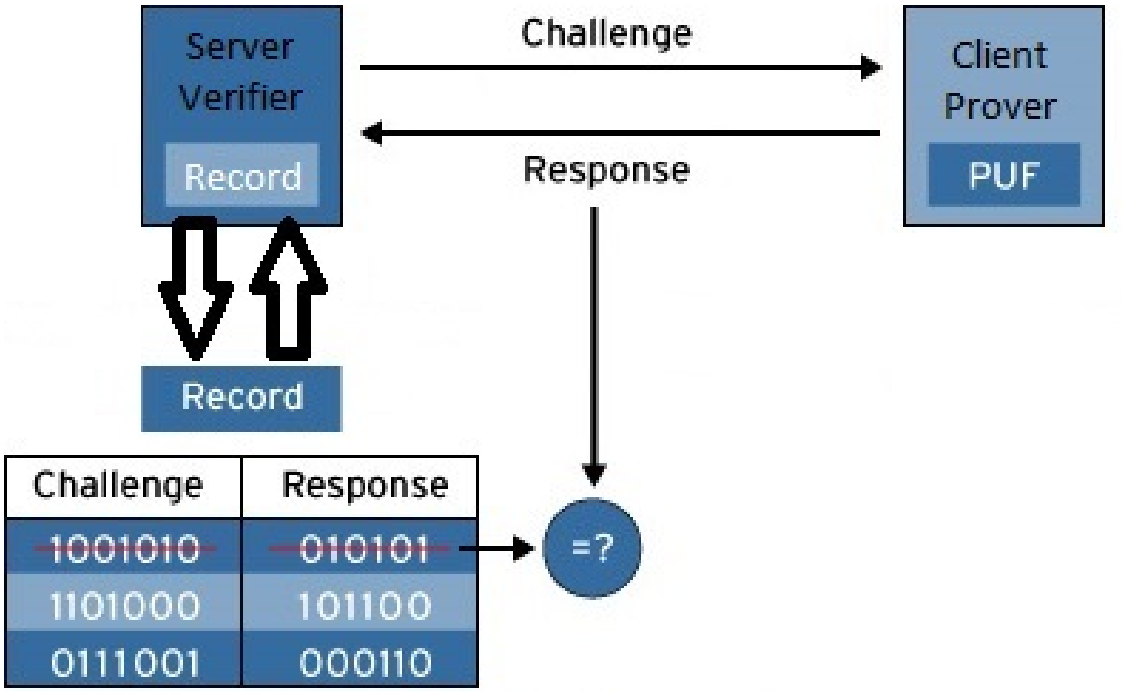


Simple PUF protocol example



Challenge	Response
~~1001010~~	~~010101~~
1101000	101100
0111001	000110

Phase 1: Enrollment

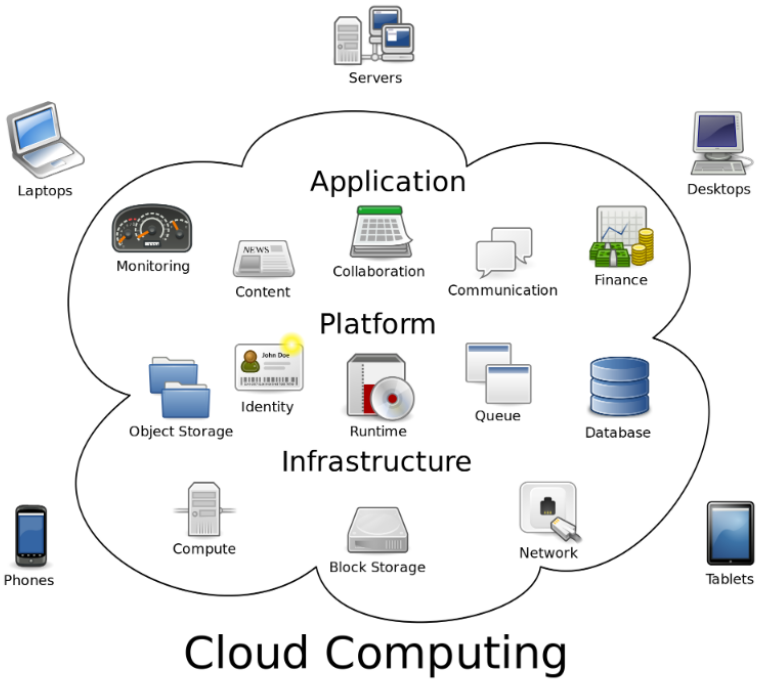


Challenge	Response
~~1001010~~	~~010101~~
1101000	101100
0111001	000110

Phase 2: Authentication

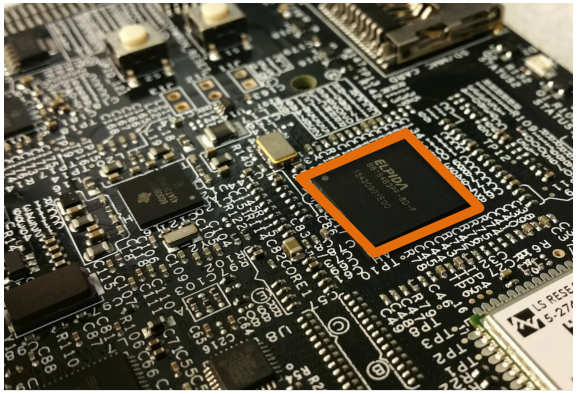
Cloud, fog or mist?

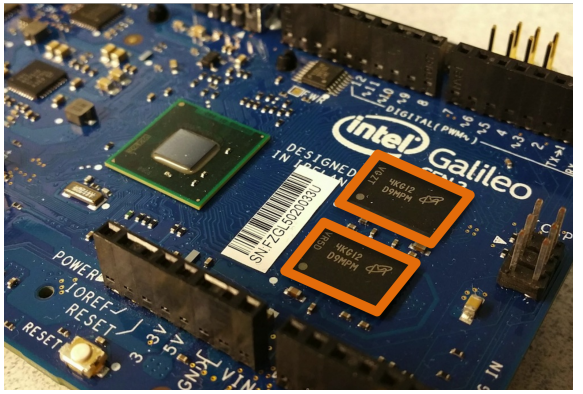
- What about the diversity of devices?
- We would need to use a weak PUF.
- But, an additional problem that has been hard to tackle is using weak PUFs at runtime.
- Is hardware flexible enough?
- If the cloud is not always secure, can we trust the fog or the mist?



Data remanence DRAM PUF

- **Extract decay-based DRAM PUF** instances from unmodified commodity devices during run-time of the Linux system
  - No extra chips needed for PUF
  - Exploit hardware which is on-board anyway
- Through extensive experiments, we determine that DRAM PUFs exhibit **robustness, uniqueness, and stability**
- It is thus possible to **design protocols** for device authentication and secure channel establishment that draw their security from the time-dependent decay of DRAM cells

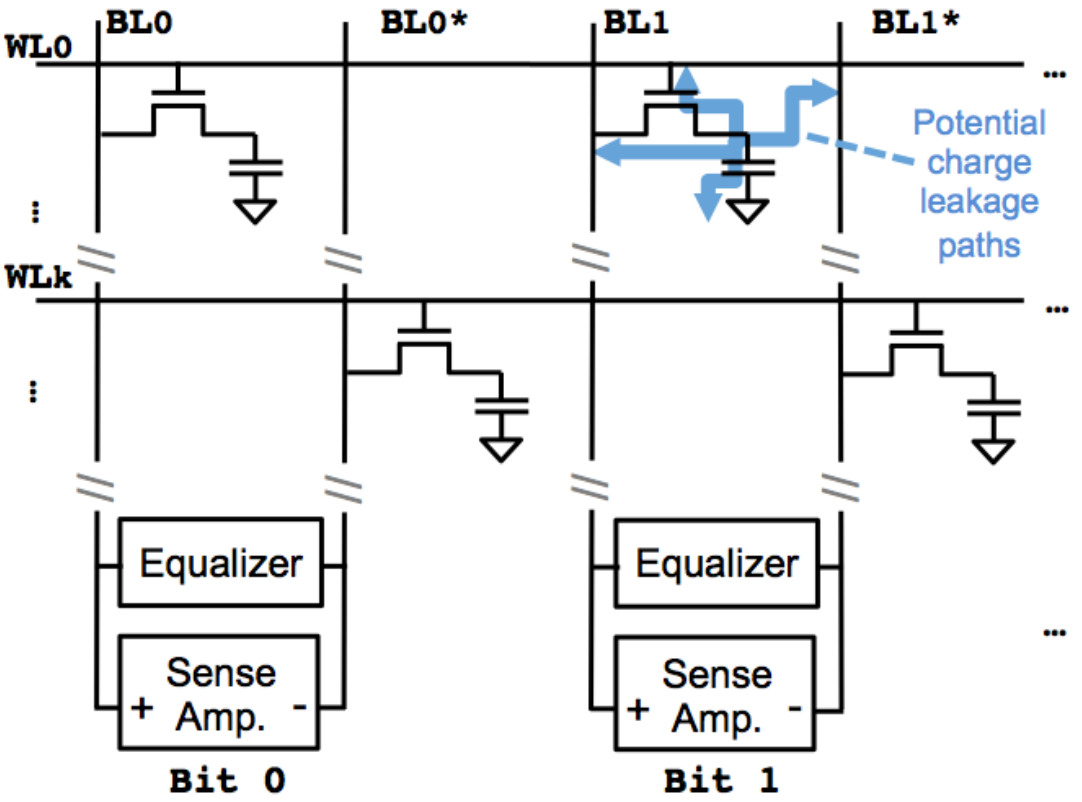




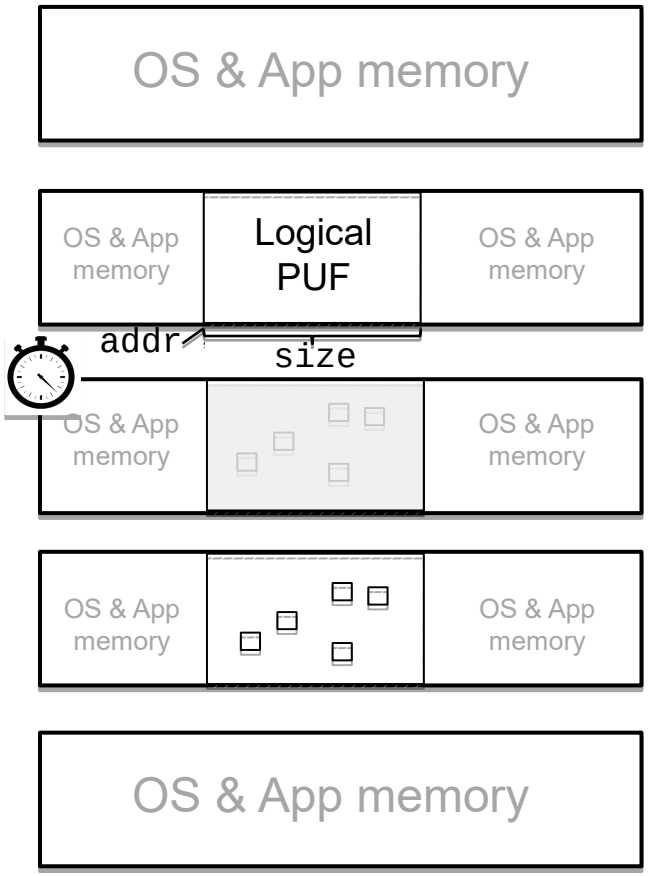
Experimental platforms
- Pandaboard (top)
- Intel Galileo (bottom)

DRAM model

- A DRAM cell consists of a capacitor and a transistor
- Each bit is stored as charge
  - Charge leakage
  - DRAM refresh
- Accessing a word will refresh the whole row
- Due to the manufacturing variations among DRAM cells, some cells decay faster than others, which can be exploited as a PUF



DRAM PUF model



(1) DRAM for ordinary use

(2) PUF region (in grey) is initialized and the DRAM **refresh is disabled**

(3) PUF cells decay for time *t*

(4) Read out the DRAM to extract the PUF measurement

(5) DRAM return to normal usage

Implementation

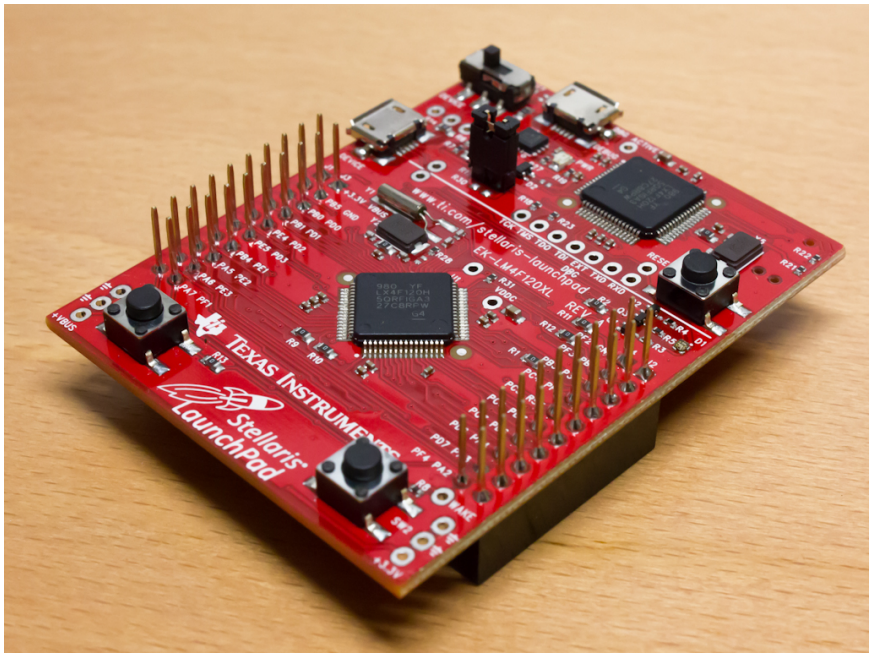
Two approaches

- Firmware
  - DRAM is not used by firmware, so the whole DRAM refresh can be disabled
- Kernel module
  - Selective DRAM refresh
  - Read a word in each DRAM row, and thus, refresh the DRAM used by the system and applications

Data remanence in intrinsic SRAM PUFs

- Data remanence
  - Dependent on temperature
  - Exists on both DRAMs and SRAMs
  - Can be very short-lasting on SRAMs (tens of milliseconds)

- SRAMs are no longer individual modules
  - Usually Package-on-Package
  - Sometimes on-die
  - May serve as cache
  - User-space programs have access, but attacks are more difficult



PUFs, IoT and the Cloud

- If we can use PUFs at runtime on IoT devices, why not use this also on the Cloud?
- We do need better security solutions for the cloud; more scalable, more agile.
- Hardware can offer this: Different devices get different privileges on the same account.
- If we can provide security for machines, we should be able to provide security also for people.

Advantages and potential PUF solutions

- Inherent solutions: Low cost
- Automation: The machine authenticates itself
- Server-client security
- Scalability
- Turn attacks into security features: Rowhammer PUF
- Use communication modules for security: WLAN/WiFi modules
- Use communication channels as PUFs

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Discussion