Fault attacks on white-box computations

L'attaque en faute : la bête noire des boîtes blanches

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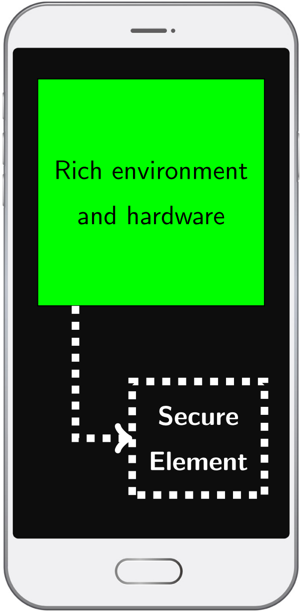

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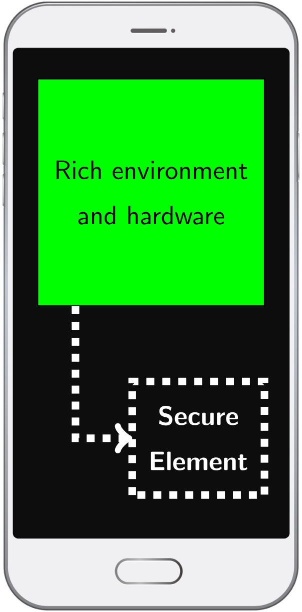
The industry has repeatedly investigated the possibility of running sensitive processes on them.

However, access to a secure environment is not ensured !



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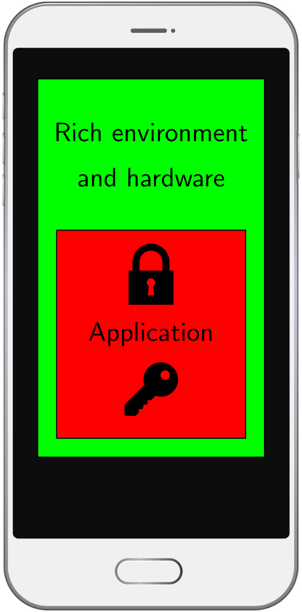

In the face of this, a lot of research has been done on the execution of sensitive operations on uncontrolled environment.

This is called the white-box model. It tries to reproduce the features of a root of trust, without it.

The considered applications are mainly found in cryptography.

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The goal is obviously to make attacks as complicated and time-consuming as possible, even using advanced tools (such as Ghidra, IDA Pro, Radare2...). High skills in reverse engineering would also be required.

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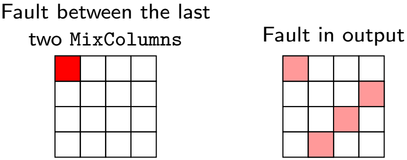
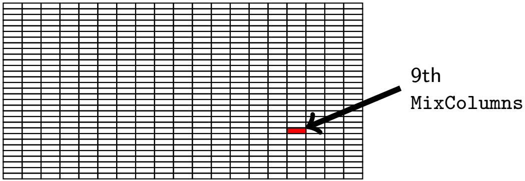
While reverse engineering such an implementation is, as intended, costly, difficult and lengthy, binary instrumentation brings another danger: automated and easy to conduct attacks.

With the help of tools such as QBDI or Rainbow, one can effectively reproduce hardware attacks on obfuscated programs or white-boxes.

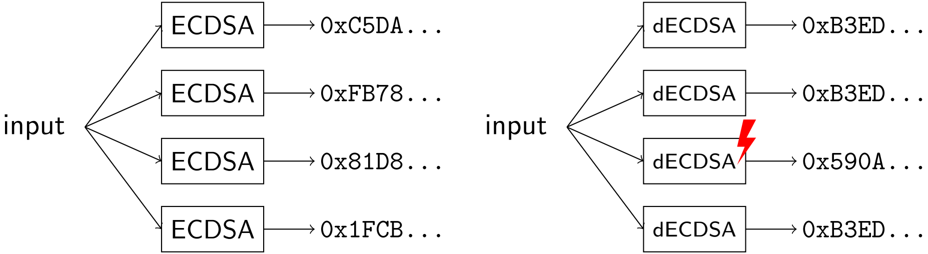
Consider the classic fault attack on AES [4].





This attack is directly transposable to the white-box model [7].

The ECDSA fundamentally relies on entropy, and operates on large values. This makes white-box implementations particularly tedious.



Having deterministic results makes differential fault attacks possible [8] [1].

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- Besides, asymmetric cryptosystems are seen as handy in the industry as they provide flexible use cases.
- Finally, white-box cryptography should now also aim to address the quantum threat [3].

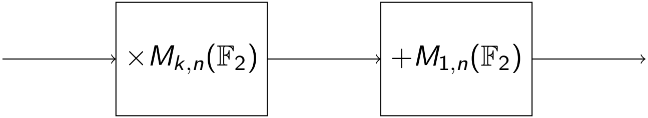
Are there any asymmetric, quantum-proof and white-boxable algorithms ?

In 2015, PQCRYPTO officially made an initial recommendation on the McEliece cryptosystem for public-key encryption, with $n = 6960$ [6].

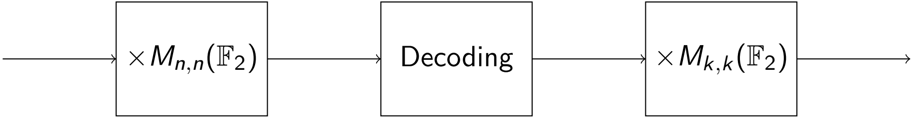
PQCRYPTO
ICT-645622

Introduced in 1978, the McEliece cryptosystem is an asymmetric algorithm heavily relying on linear error-correcting codes [5].

The encryption process uses a public key and simply consists of a matrix multiplication followed by an addition.



The decryption process uses a private key and can be summarized as a matrix multiplication, a decoding process, and another matrix multiplication.


$\times M_{n,n}(\mathbb{F}_2)$
Decoding
$\times M_{k,k}(\mathbb{F}_2)$

All of these components are easily encodable, except for the decoding process.

Error-correction has a good diffusion on large data blocks, hence the difficulty to predict at compile time, and the robustness against fault attacks [2].

To make a white-boxed McEliece cryptosystem, different research axes were explored :

- explore other error-correcting codes outside of the Goppa ones ?
- modify the way codes are exploited in McEliece ?

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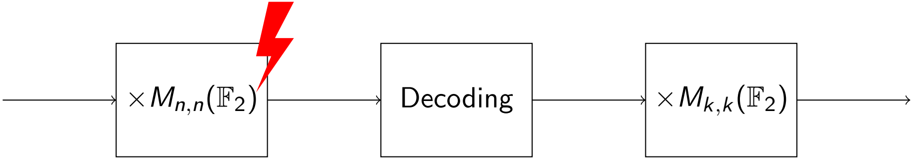
However, we did found a working attack based on fault injection targeting the classic way of implementing this cryptosystem.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Can the attack be successfully adapted to reach them too ?

This requires to reproduce it using data mutation.

Although the white-box model is very useful, implementations require a lot of efforts to be deployed and maintained, and provide limited resilience.

Binary instrumentation shows how threats such as fault attacks can transpose or add themselves when one switches to this model, and how a lot of the original countermeasures can become inefficient in it.

The McEliece cryptosystem, despite the size of its keys, seems to offer relevancy in this domain of research.

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