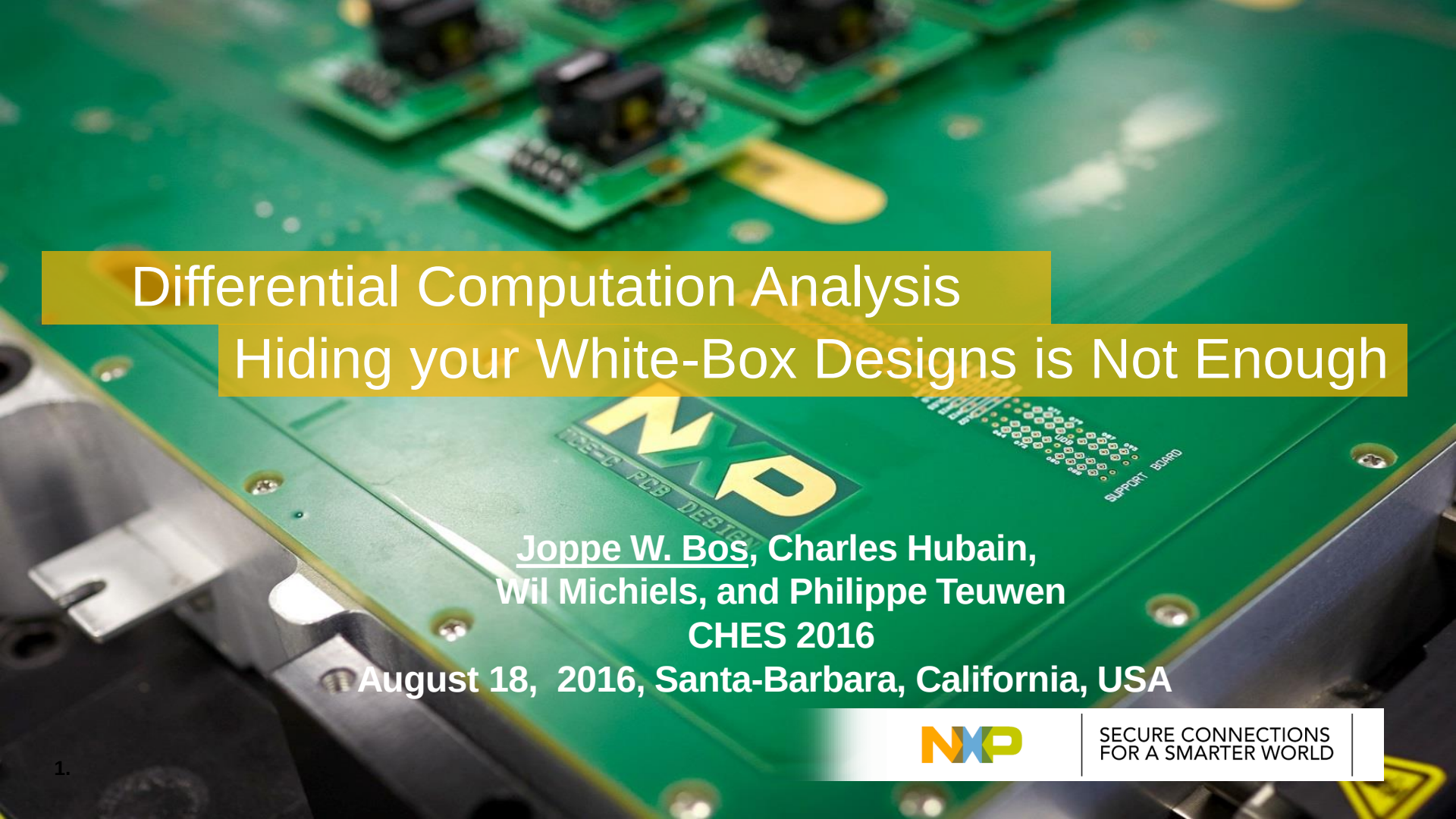


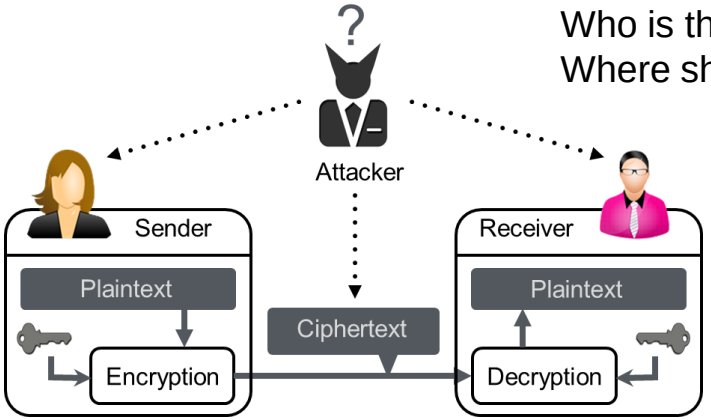
Differential Computation Analysis
Hiding your White-Box Designs is Not Enough

Joppe W. Bos, Charles Hubain,
Wil Michiels, and Philippe Teuwen

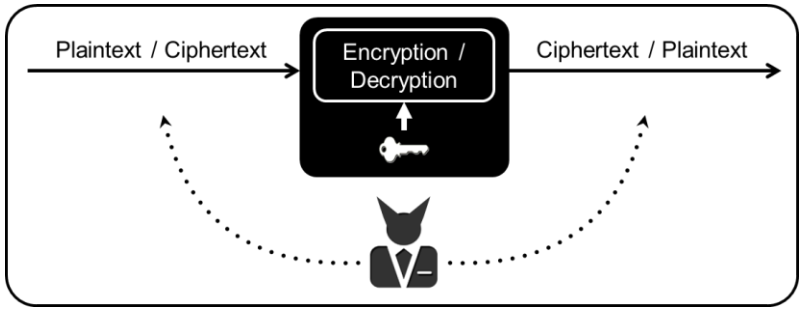
CHES 2016

August 18, 2016, Santa-Barbara, California, USA

SECURE CONNECTIONS FOR A SMARTER WORLD



Who is the attacker? External adversary, user, virus?
Where should we assume the attacker to be? What is realistic?



Endpoints are trusted parties
Attacker “observes” data being transferred

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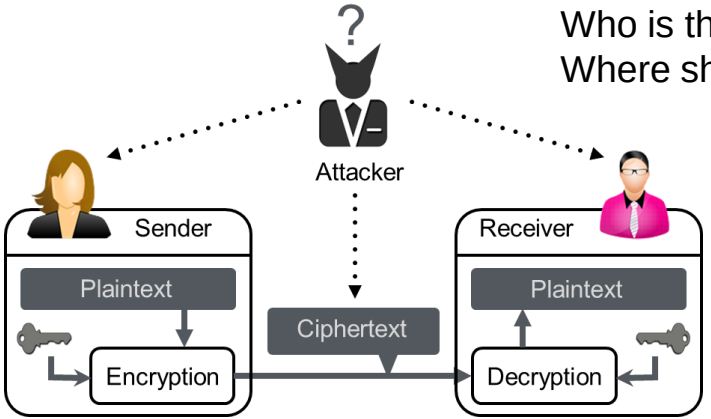

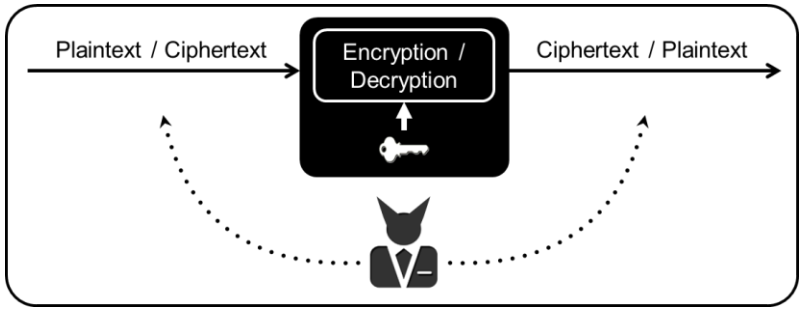

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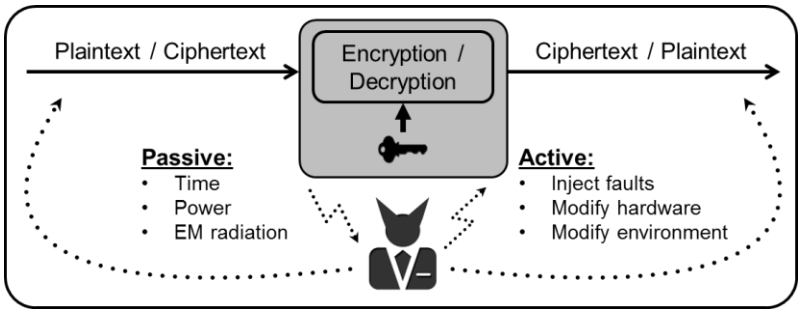

This is why you attend this conference!

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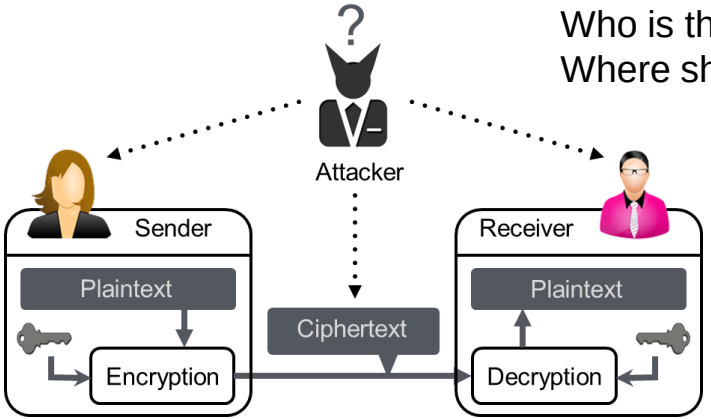

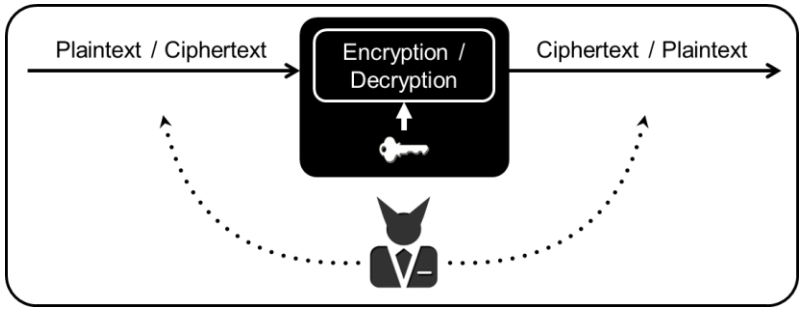

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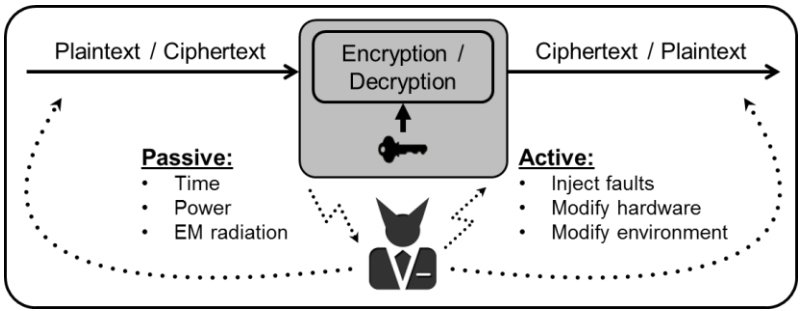

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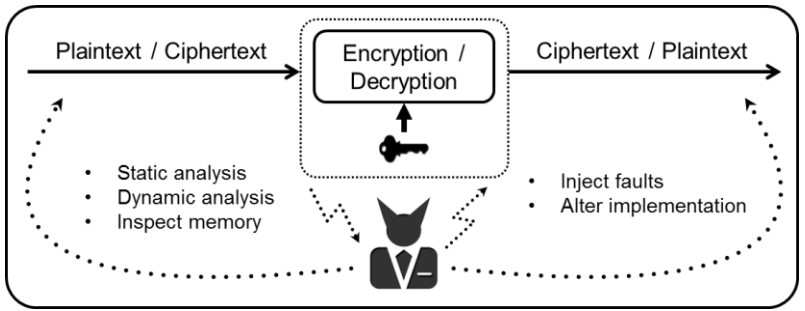

Adversary owns the device running the software.

Where is this used in practice?

Original use-case for white-box crypto is *digital right management*.

For example: streaming content, protecting DVD’s etc

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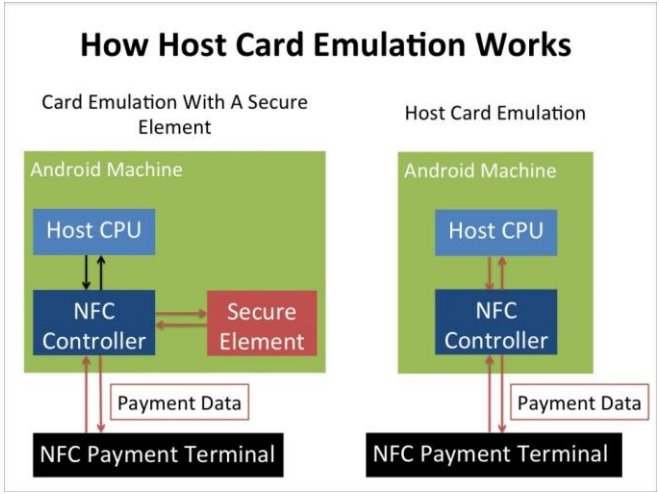


Source: Business Insider

Recent trend

Use *Host Card Emulation* (HCE) to communicate using *Near Field Communication* (NFC)
→ Replace the secure element with software.

Protection of the cryptographic key? How?
White-box implementation!

Huge demand for practical + secure white-box

- 2014: VISA + Mastercard support HCE
- [Berg Insight]: **86%** of the Point of Sale devices in North America and **78%** in Europe will support NFC by 2017.
- [IHS research]: By 2018, 2/3 of all shipped phones will support NFC.
- → the protocols used need to use (and store!) AES / DES keys
  → need for secure **white-box cryptography**.

Security of WB solutions - Theory

White box can be seen as a form of code obfuscation

- It is known that obfuscation of **any** program is impossible

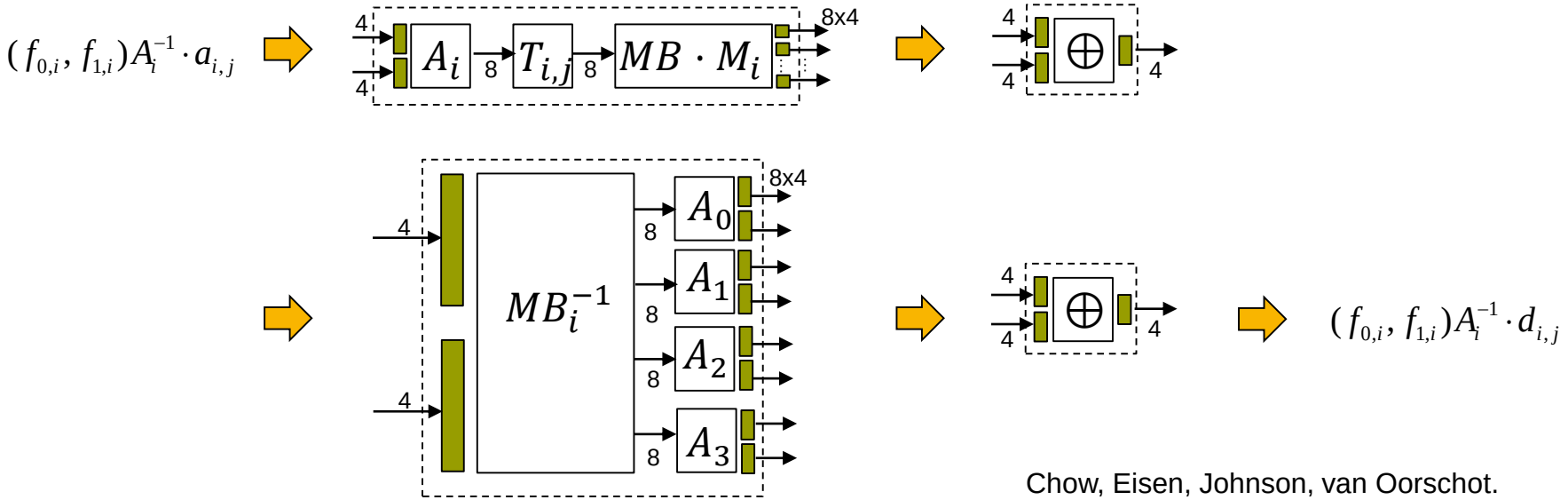
Barak, Goldreich, Impagliazzo, Rudich, Sahai, Vadhan, Yang. On the (im)possibility of obfuscating programs. In CRYPTO 2001

- Unknown if a (sub)family of white-box functions can be obfuscated
- If secure WB solution exists then this is protected (by definition!) to **all** *current* and *future* side-channel and fault attacks!

Practice

- Only results known for symmetric crypto
  (all academic designs of standard crypto broken)
- Convert algorithms to sequence of LUTs
- Embed the secret key in the LUTs
- Obfuscate the LUTs by using encodings

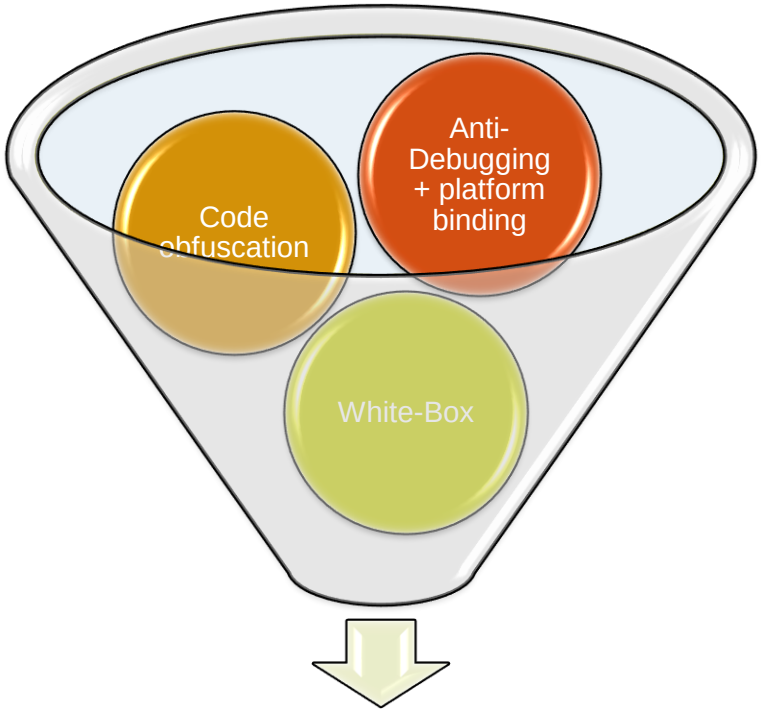
Obfuscating the LUTs



Chow, Eisen, Johnson, van Oorschot. White-box cryptography and an AES implementation. In SAC 2002.

Size of implementation: ≈ 700 kB

White box crypto - practice



In practice the white box is the most essential but a **small part** of the entire software implementation

- Strong code obfuscation
- Binary is “glued” to the environment
  - Prevent code-lifting
- Support for traitor tracing
- Mechanism for frequent updating

More details see the invited talk at EC 2016 *Engineering Code Obfuscation* by Christian Collberg

Effort and expertise required

Previous effort

Previous WB attacks were WB specific which means knowing

- the *encodings*
- which *cipher operations* are implemented by
- which (network of) *lookup tables*

Attack

1. time-consuming reverse-engineering of the code
2. identify which WB scheme is used + target the correct LUTs
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Our approach

Assess the security of a WB implementation

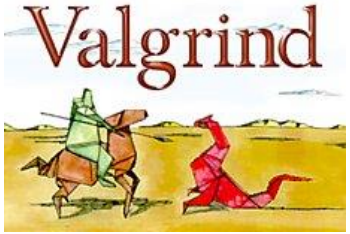
- ✓ Automatically and very simply (see CHES challenge)
- ✓ Without knowledge of any implementation choices
  → only the algorithm itself
- ✓ Ignores all (attempts) at code-obfuscation

Tracing binaries

- Academic attacks are on open design
- In practice: what you get is a binary blob

Idea: collect information using using *dynamic binary instrumentation* tools (→ visual representation → use traces to find correlation)

- Record all instructions and memory accesses.



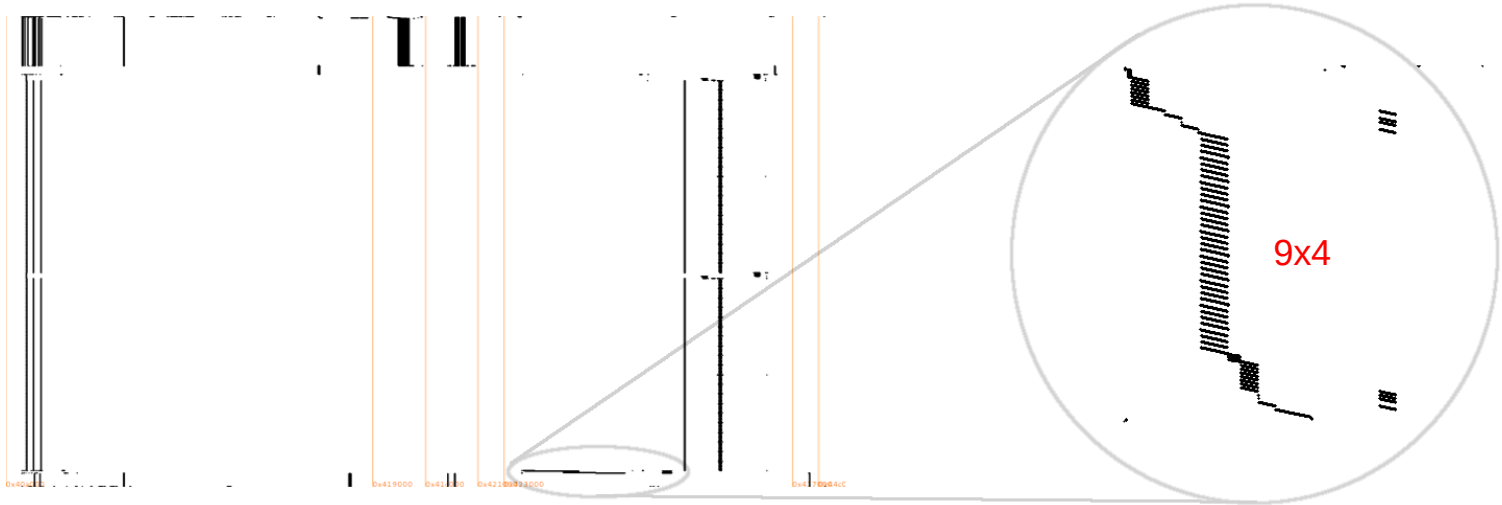
Examples of the tools we extended / modified

- Intel PIN (x86, x86-64, Linux, Windows, Wine/Linux)
- Valgrind (idem+ARM, Android)

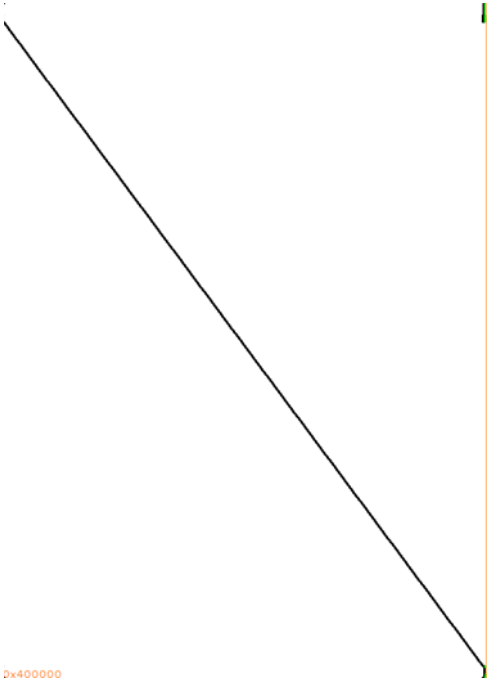
Trace visualization

Based on Ptra, an unreleased Quarkslab tool presented at SSTIC 2014

Visual crypto identification: code



Visual crypto identification: code?



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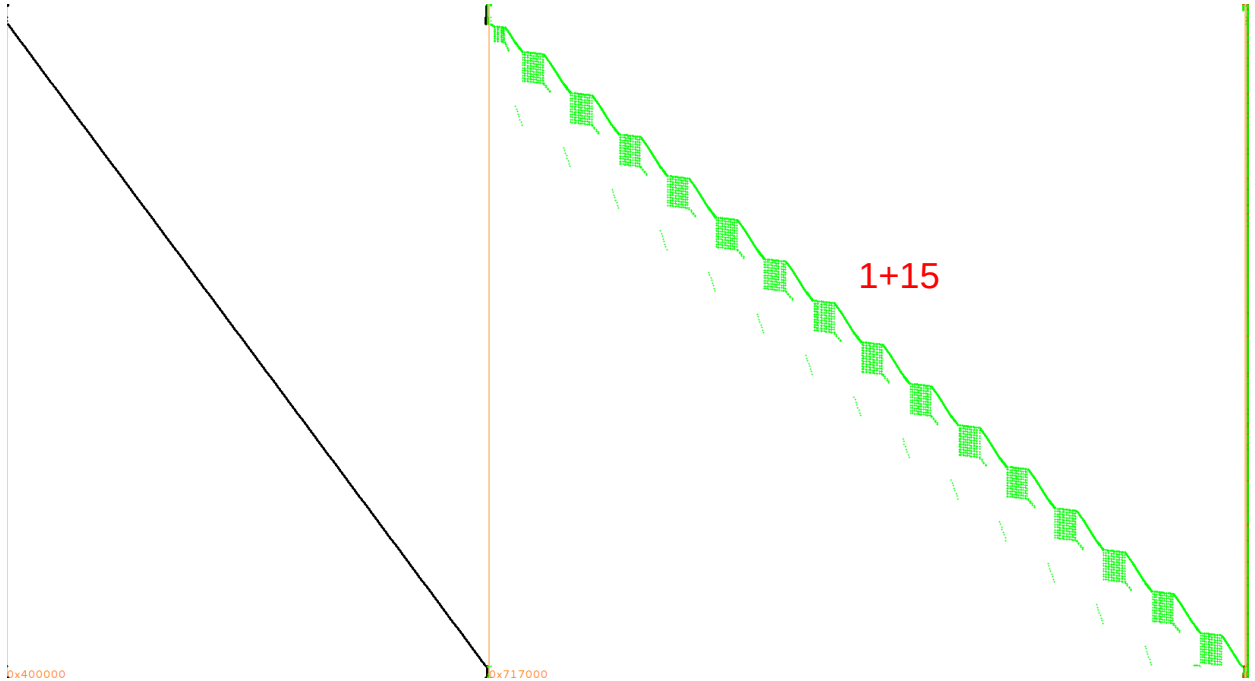

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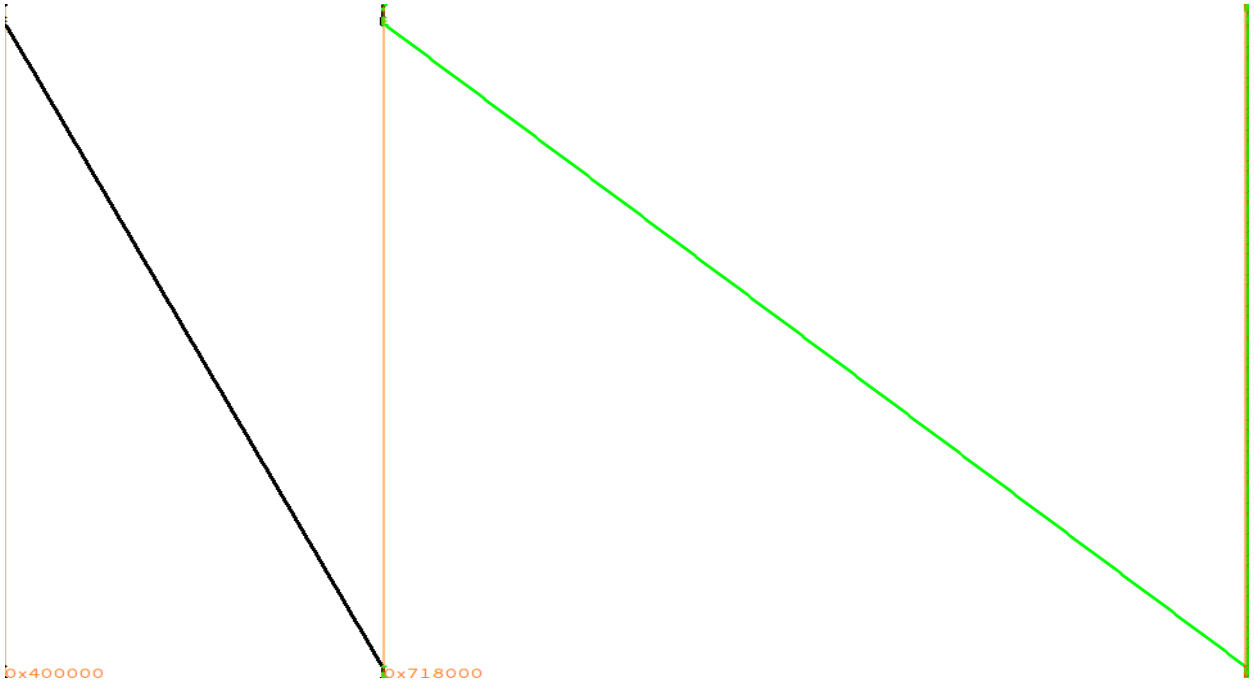
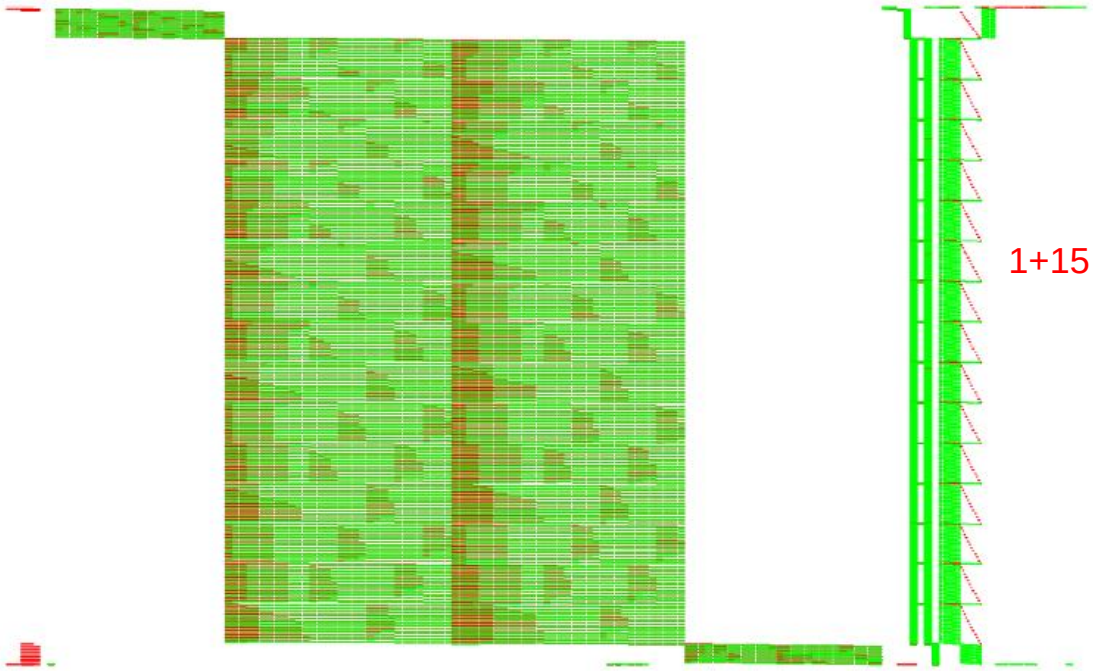


Visual crypto identification: stack!



Differential Computation Analysis

Naïve approach: Port the white-box to a smartcard and measure power consumption

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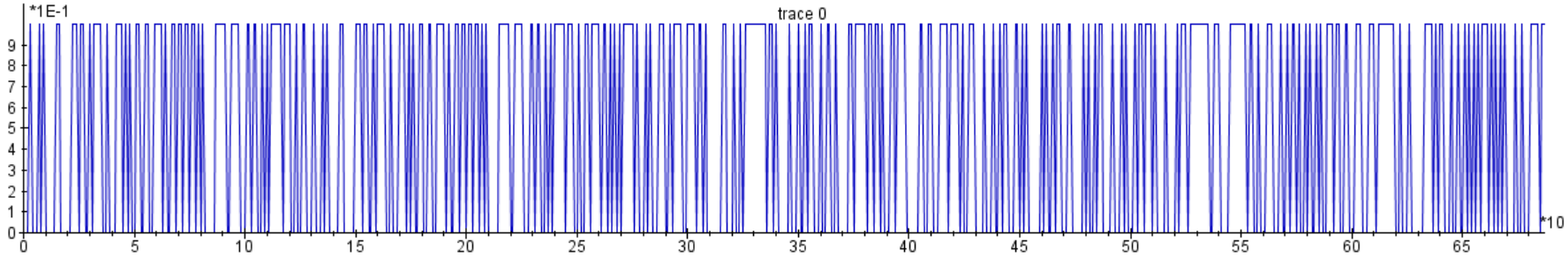
Better approach: each bit is equally important

→ Serialize bytes in a succession of bits



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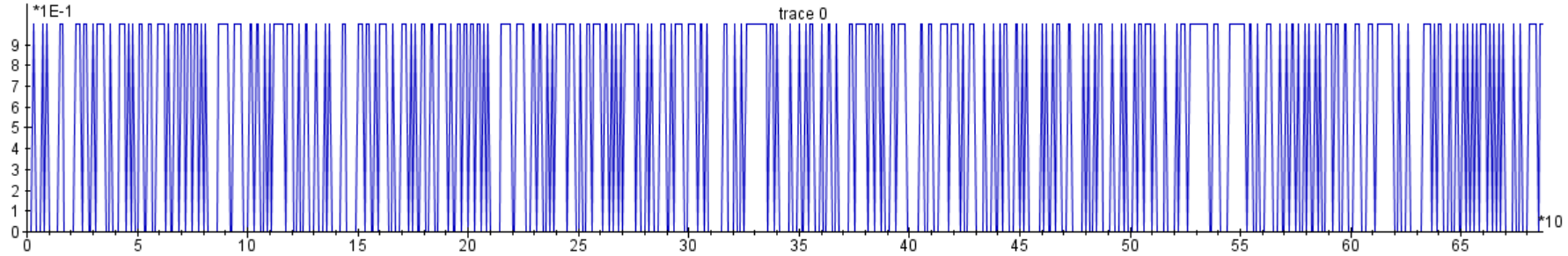

Visual challenge: try to identify the rounds
(Hint: auto-correlation can reveal them!)

DCA: DPA on software traces

HW analogy: this is like probing each bus-line individually ***without any error***

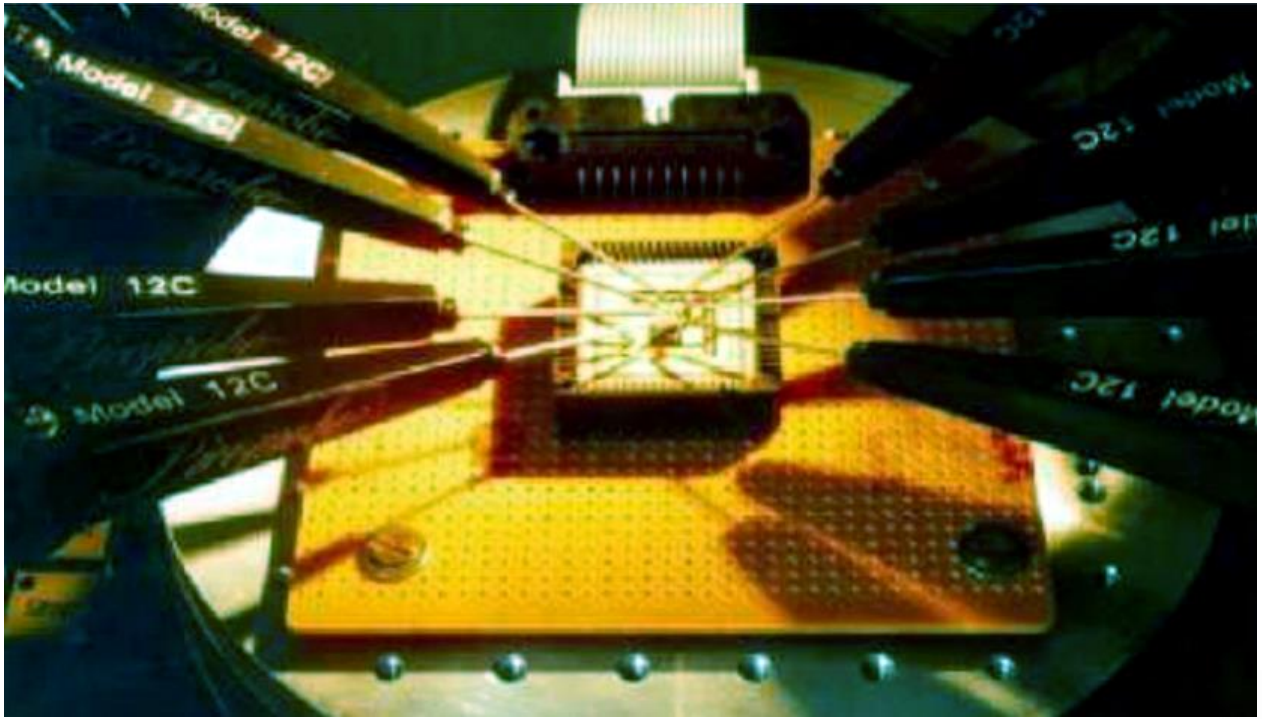

Image source: Brightsight

Results

WB implementations should not leak any side-channel information (by definition of the WB attack model): let's check!

WB implementation	Algorithm	#traces
Wyseur challenge, 2007	DES (Chow+)	65
Hack.lu challenge, 2009	AES (Chow)	16 (no encodings)
SSTIC challenge, 2012	DES	16 (no encodings)
Klinec implementation, 2013	AES (Karroumi, dual ciphers)	2000 → 500

Intuition why this works:
Encodings do not sufficiently hide correlations when the correct key is used.

See also: P. Sasdrich, A. Moradi, and T. Güneysu. White-box cryptography in the gray box - a hardware implementation and its side channels. In FSE 2016.

A lot of potential for follow-up work!

Use the extended research results from the grey box world

Countermeasures

- Use random masks / delays → white-box model allows to disable entropy source
- Use static random data within the white-box itself?
- Use ideas from threshold implementation? [TI]
- Better DBI framework detection mechanisms
- DCA might fail when using large encodings → larger LUTs → algebraic attacks still work

[TI] S. Nikova, C. Rechberger, and V. Rijmen. Threshold implementations against side-channel attacks and glitches. In Information and Communications Security, 2006.

Other attacks

Riscure has proven software fault attacks (DFA) work too [RISCURE].

Once there are countermeasures against DCA and DFA, can we use any of the other known advanced SCA in this setting?

[RISCURE] E. S. Gonzalez, C. Mune, Job de Haas: Unboxing the White-Box: Practical Attacks Against Obfuscated Ciphers. Black Hat Europe 2015.

Side-Channel Marvels

SCA-related projects

https://github.com/SideChannelMarvels

Any help to complete our collection of open whitebox challenges and attacks or to improve our tools is highly appreciated!

Deadpool

C ★ 25 6

Repository of various public white-box cryptographic implementations and their practical attacks.

Updated 10 days ago

Tracer

C++ ★ 25 7

Set of Dynamic Binary Instrumentation and visualization tools for execution traces.

Updated on Apr 24

JeanGrey

Python ★ 0 0

A tool to perform differential fault analysis attacks (DFA).

Updated on Apr 18

Orka

★ 4 1

Repository of the official Docker image for SideChannelMarvels.

Updated on Apr 14

Daredevil

C++ ★ 10 4

A tool to perform (higher-order) correlation power analysis attacks (CPA).

Updated on Apr 11

Conclusions

- Software-only solutions are becoming more popular
  - white-box crypto
- Traditional (DRM) and new use-cases HCE (payment, transit, …)
- Level of security / maturity of many (all?) WB schemes is questionable
  - Open problem to construct asymmetric WB crypto
  - Industry keeps design secret
- DCA is an automated attack which can be carried out without any expertise
  - Counterpart of the DPA from the crypto HW community
- This hopefully sparkles more interest in both cryptographic and cryptanalytic white-box research!

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