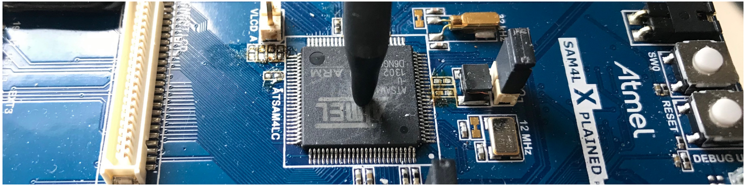

Multi-Tuple Leakage Detection and the Dependent Signal Issue

Olivier Bronchain Tobias Schneider François-Xavier Standaert

CHES 2019, Atlanta, USA

European Research Council
Established by the European Commission

GROUPE CRYPTO

UCLouvain

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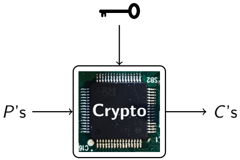
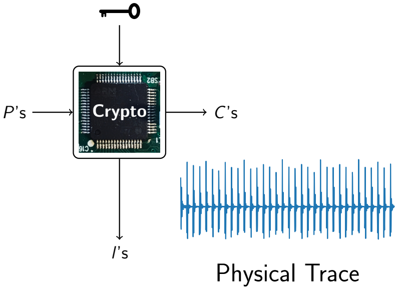


Encryption on physical devices:

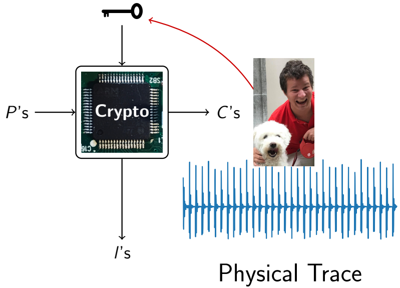
Side-Channel Issue



Encryption on physical devices:

- With any physical signals

Side-Channel Issue



Encryption on physical devices:

- With any physical signals
- Possibly containing secret information

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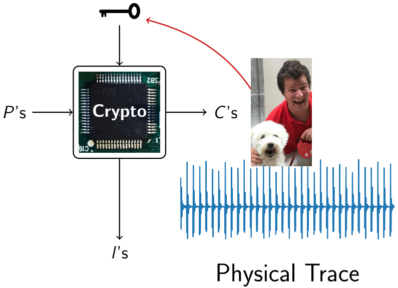

Encryption on physical devices:

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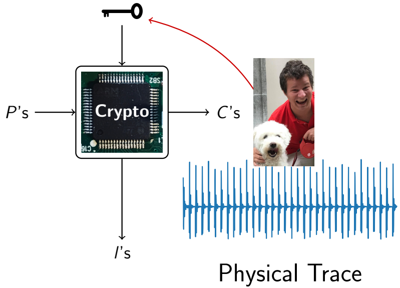
Side-channel Attacks:

- Known to be hard to prevent
- Hard to evaluate as well

Side-Channel Issue



Encryption on physical devices:

- With any physical signals
- Possibly containing secret information

Side-channel Attacks:

- Known to be hard to prevent
- Hard to evaluate as well

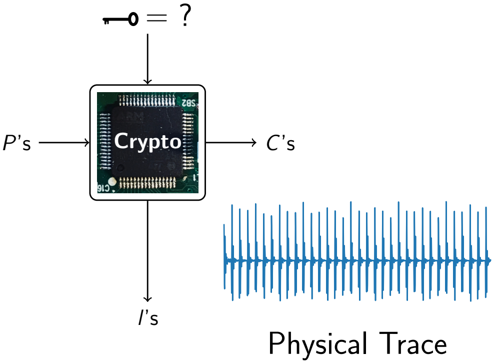
Two evaluation approaches:

- Attack based
- Leakage detection

Attack Based Evaluation

Can directly mount attacks:

1. Collect measurements



Attack Based Evaluation

Can directly mount attacks:

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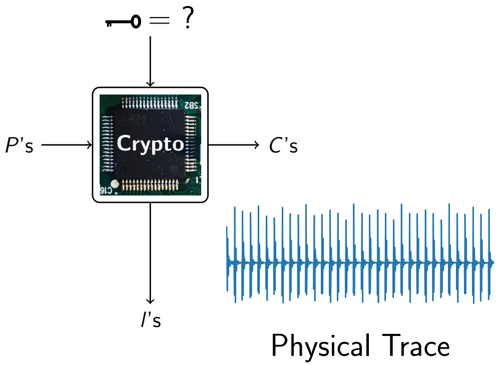
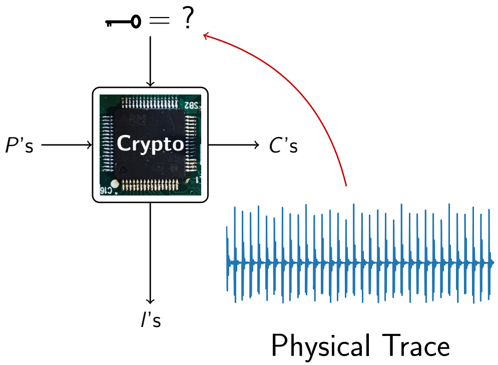


Attack Based Evaluation

Can directly mount attacks:

1. Collect measurements
2. Perform an attack
3. Retrieve the correct sub-key



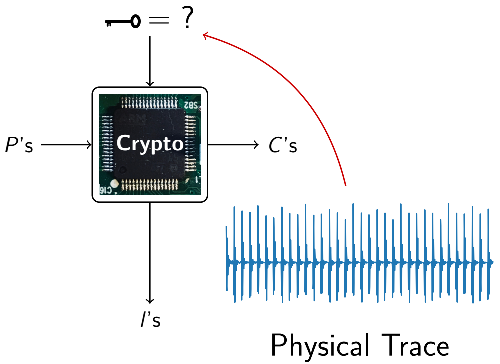
Attack Based Evaluation

Can directly mount attacks:

1. Collect measurements
2. Perform an attack
3. Retrieve the correct sub-key

This requires:

1. Long measurement period
2. Skilled/expert knowledge
3. Distinguish 1 sub-key within 256



Leakage Detection Based Evaluation

Leakage detection searches for dependency between manipulated data and physical traces.

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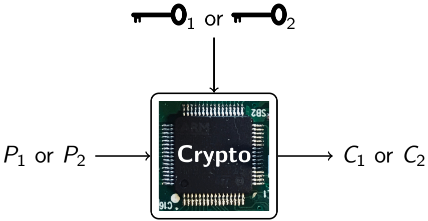
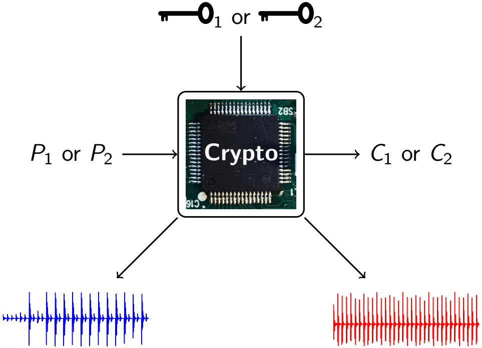


- Feed the core with two different sets of inputs

Leakage Detection Based Evaluation

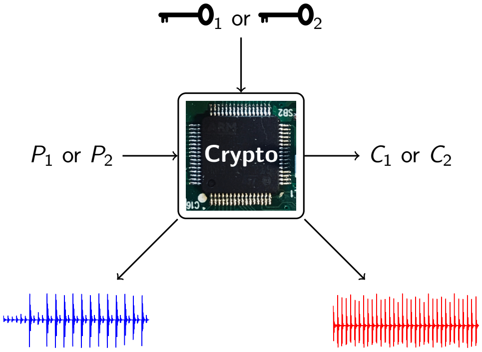
Leakage detection searches for dependency between manipulated data and physical traces.



- Feed the core with two different sets of inputs
- Record the corresponding traces

Leakage Detection Based Evaluation

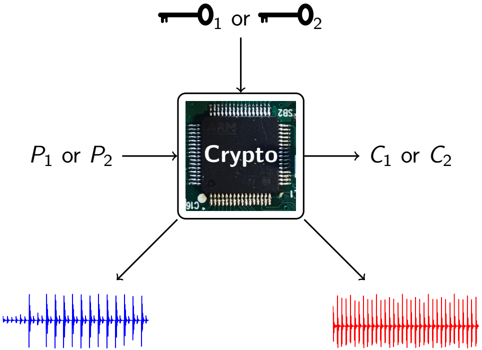
Leakage detection searches for dependency between manipulated data and physical traces.



- Feed the core with two different sets of inputs
- Record the corresponding traces
- Observe differences between the two sets

Leakage Detection Based Evaluation

Leakage detection searches for dependency between manipulated data and physical traces.

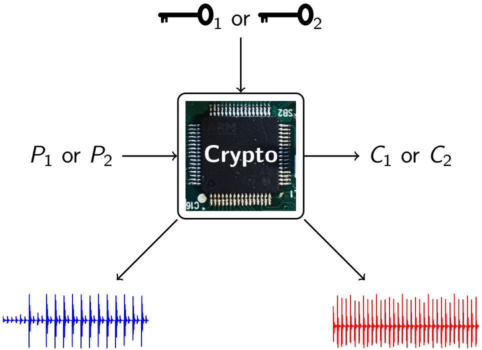


How does it compare with attack based evaluations:

- Shortened measurement period (Possibly)
- No skilled/expert knowledge

Leakage Detection Based Evaluation

Leakage detection searches for dependency between manipulated data and physical traces.



How does it compare with attack based evaluations:

- Shortened measurement period (Possibly)
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A good first check but:

- Risk of false positives and false negatives

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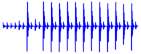
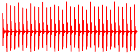
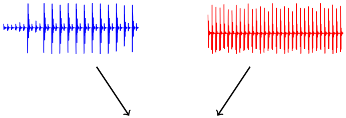
Leakage Detection

Find a difference between the two sets:





Leakage Detection



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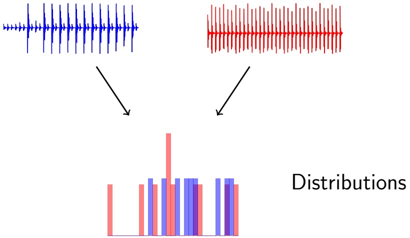
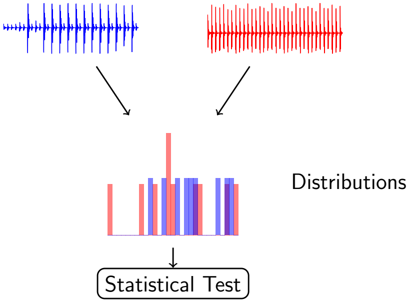
1. Select a point in time
2. Record traces to observe a distribution



Leakage Detection

Find a difference between the two sets:

1. Select a point in time
2. Record traces to observe a distribution
3. Perform a statistical test



Leakage Detection

Find a difference between the two sets:

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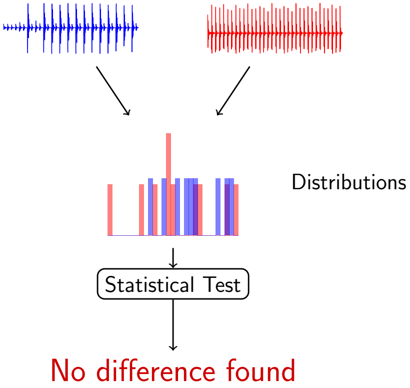
3. Perform a statistical test
4. Observe its binary output



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Find a difference between the two sets:

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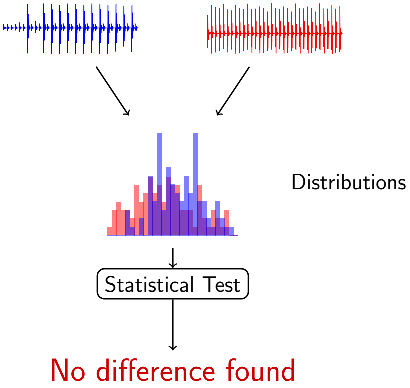
Repeat with more measurements if needed



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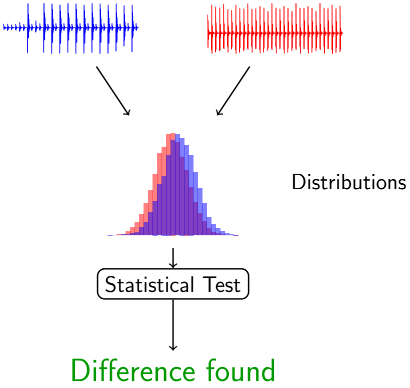

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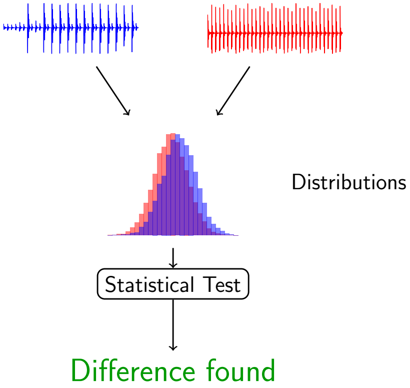

The statistical test can search for difference in:

- Means with the Welch's t-test
- Distributions with χ^2-test
- ...

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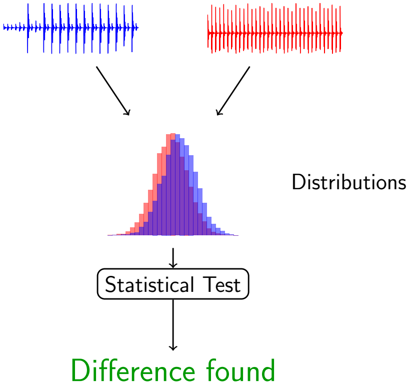

The statistical test can search for difference in:

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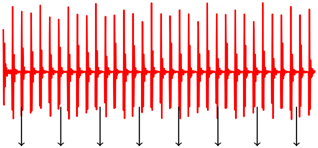
Leakage Detection: TVLA

The traces contain multiple points in time:

1. Select **all** the points in time



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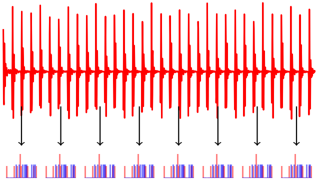

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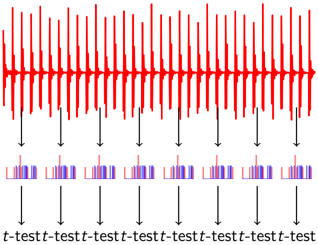
Leakage Detection: TVLA

The traces contain multiple points in time:

1. Select **all** the points in time
2. Record traces to observe a distribution
3. Perform **independent** statistical test



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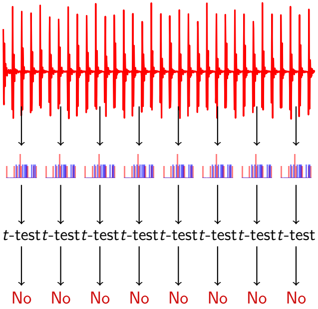

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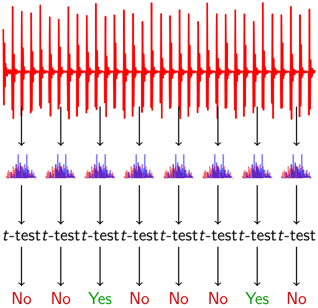

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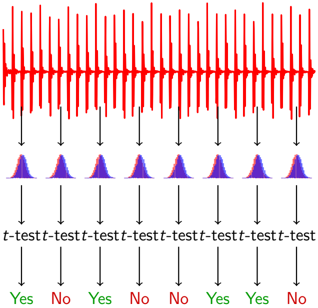

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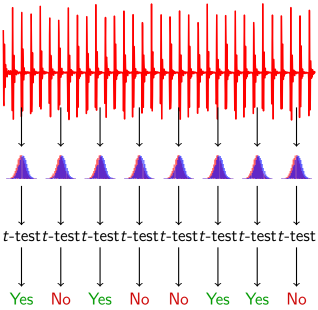

Difference found if:

- At least one of the tests goes above a threshold

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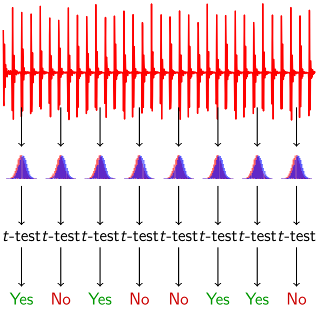
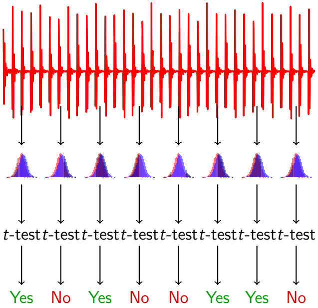


Difference found if:

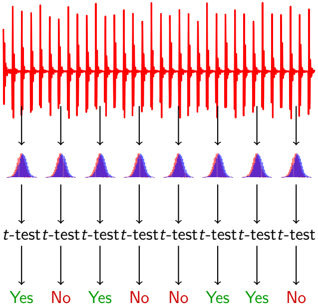
- At least one of the tests goes above a threshold
- Selected thanks to:
  - Desired confidence
  - Number of considered time samples
  - Assuming independence between them

Limitations to TVLA



TVLA performs independent t-test:

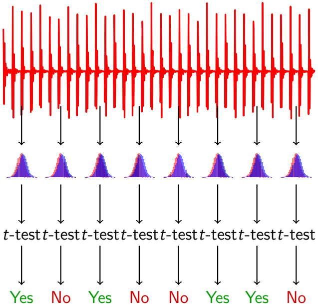
Limitations to TVLA



TVLA performs independent *t*-test:

- Impossible to take advantage of multivariate leakage

Limitations to TVLA



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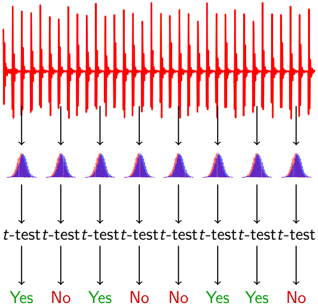

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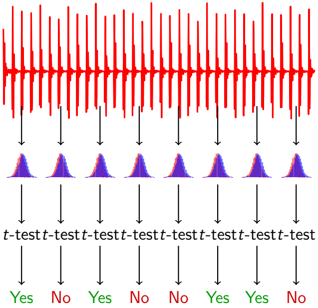
Independence in the signal is usually not met:

Limitations to TVLA



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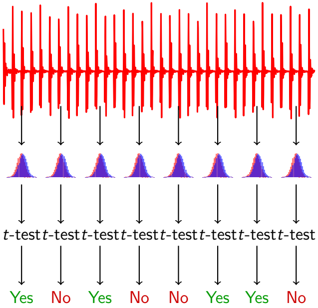
Limitations to TVLA



TVLA performs independent *t*-test:

- Impossible to take advantage of multivariate leakage
  - Could lead to reduced measurement period

Independence in the signal is usually not met:

- Wrong assumption while setting the threshold
  - Hard to interpret results (especially negative ones)

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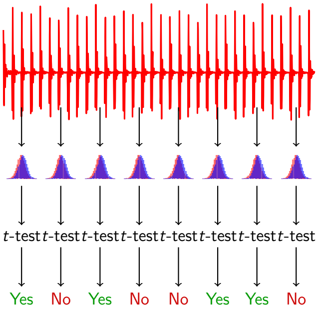
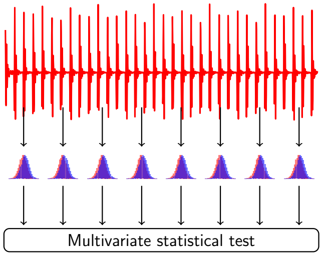
Multi-Tuple Leakage Detection: General Idea



Approach:

Multi-Tuple Leakage Detection: General Idea



Approach:

- Replace the independent tests by a single one

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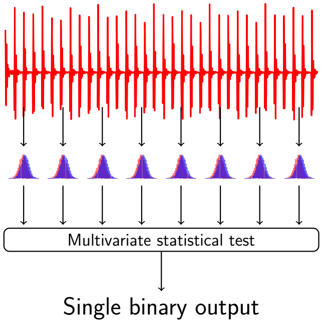

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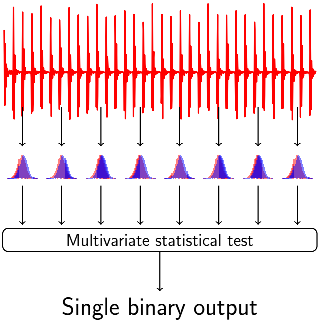

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Natural canditate: Hotelling's T^2-test

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  - Not always applicable

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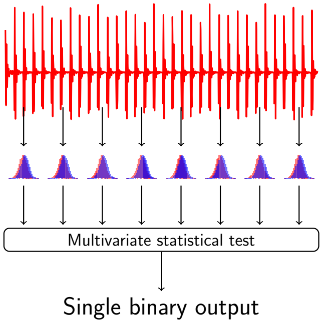

Approach:

- Replace the independent tests by a single one

Natural canditate: Hotelling's T^2-test

- Do not assume independence
- Need to invert a covariance matrix
  - Not always applicable

Heuristic alternative: D-test

- Assume independence
  - Hard to interpret results

Traces Parameter: Density

Density of informative points:

- The proportion of leaking points
- t-test showing difference with ∞ of measurements

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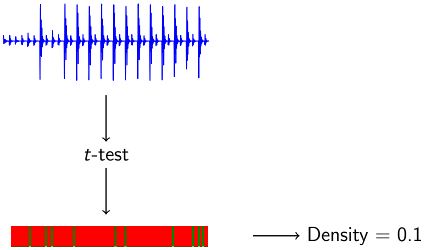

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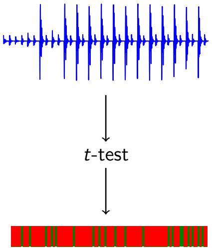

$\longrightarrow$ Density $= 0.2$

Traces Parameter: Density

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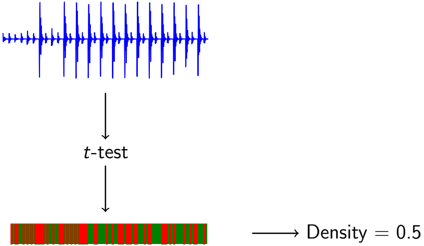

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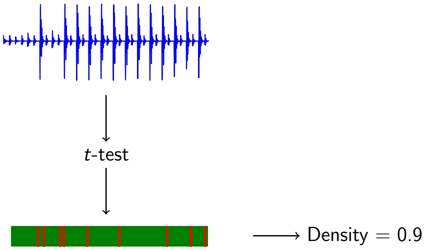

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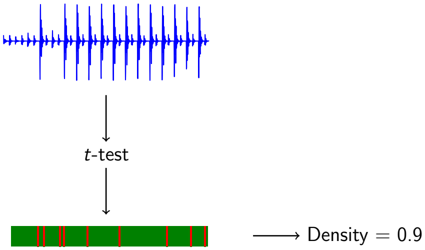


Typical settings:

- Protected software: low density, long traces
- Hardware unprotected: high density, short traces

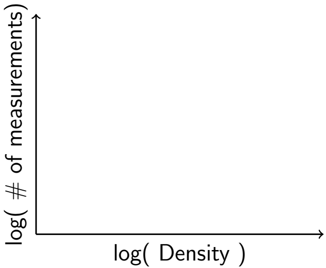
Multi-Tuple Leakage Detection: Features

From simulations with fixed trace length:

log(Density)

Multi-Tuple Leakage Detection: Features

From simulations with fixed trace length:



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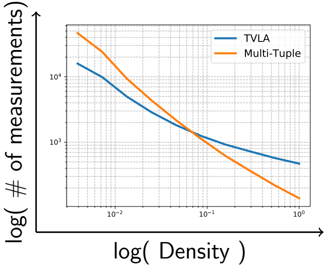
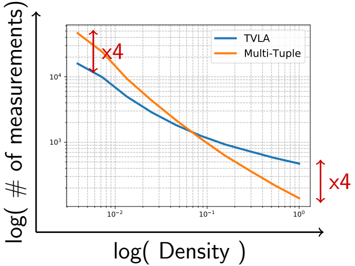


Multi-Tuple Leakage Detection: Features

From simulations with fixed trace length:

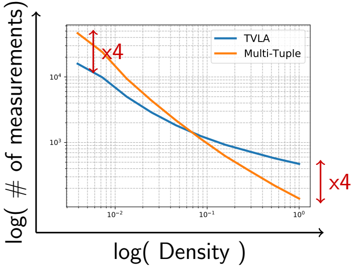
- Both methods suffer from a low density



Multi-Tuple Leakage Detection: Features

From simulations with fixed trace length:

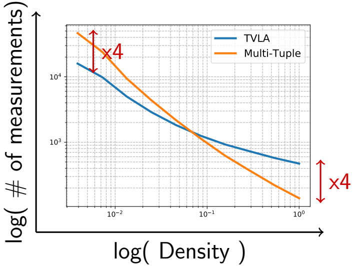
- Both methods suffer from a low density
- Multi-Tuple more than the TVLA



Multi-Tuple Leakage Detection: Features

From simulations with fixed trace length:

- Both methods suffer from a low density
- Multi-Tuple more than the TVLA



Reduced data complexity with **higher density**

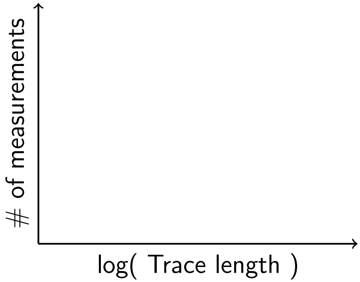
Multi-Tuple Leakage Detection: Parameters

From simulations with fixed density:

log(Trace length)

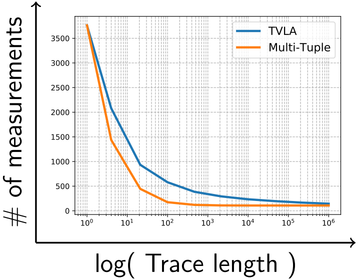
Multi-Tuple Leakage Detection: Parameters

From simulations with fixed density:



Multi-Tuple Leakage Detection: Parameters

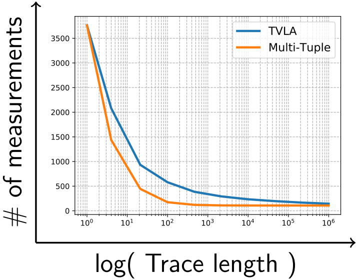
From simulations with fixed density:



Multi-Tuple Leakage Detection: Parameters

From simulations with fixed density:

- Both methods take advantage of longer traces



Multi-Tuple Leakage Detection: Parameters

From simulations with fixed density:

- Both methods take advantage of longer traces
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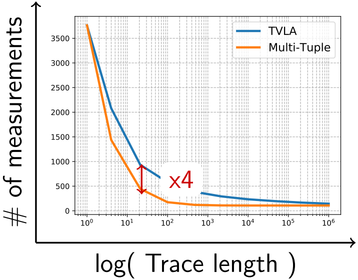

Multi-Tuple Leakage Detection: Parameters

From simulations with fixed density:

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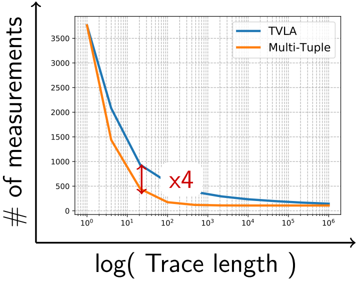
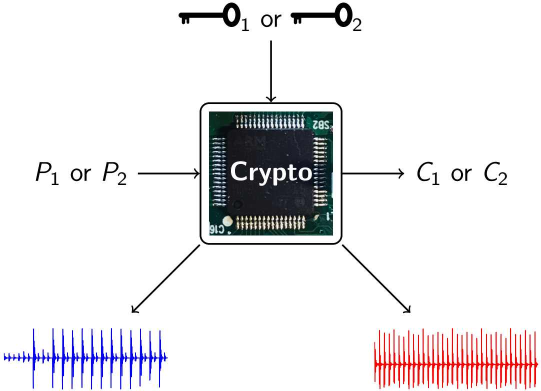


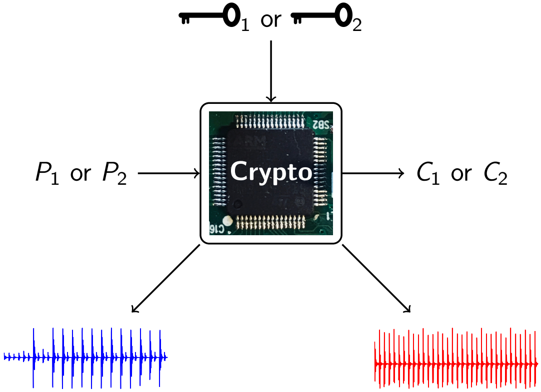
- Reduced data complexity with the **number of time samples**
- The jointly processed trace size is limited for Hotelling's test because of covariance matrix inversion (∼2000):
  - Possibility to run multiple Hotelling's tests in parallel

Practical Evaluation Scenarios



Two extreme settings:

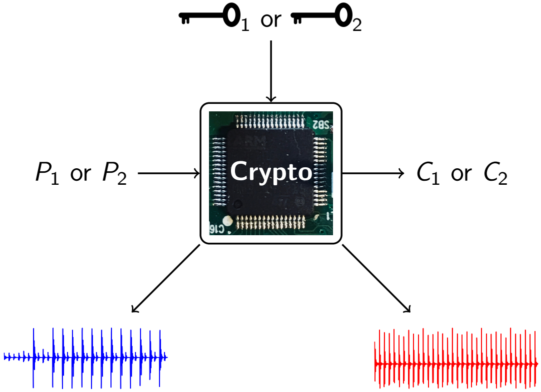
Practical Evaluation Scenarios



Two extreme settings:

- White Box: everything is known about the design

Practical Evaluation Scenarios



Two extreme settings:

- White Box: everything is known about the design
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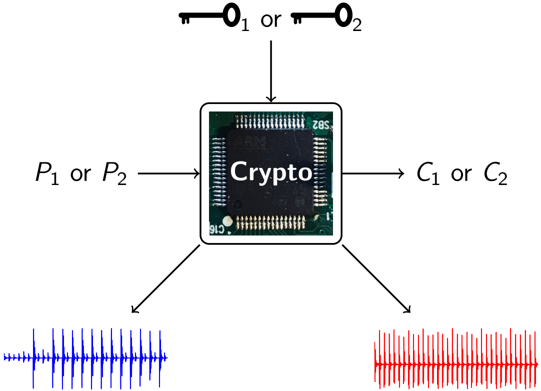

Two extreme settings:

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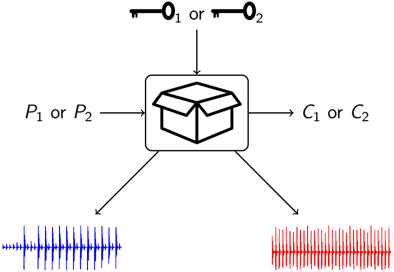
How to perform Leakage Detection in these settings ?

Practical Evaluation Scenarios: White Box

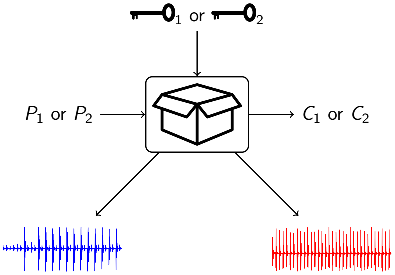
In White Box:



Practical Evaluation Scenarios: White Box

In White Box:

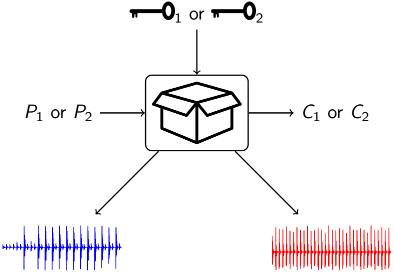
- Prior information about leaking points



Practical Evaluation Scenarios: White Box

In White Box:

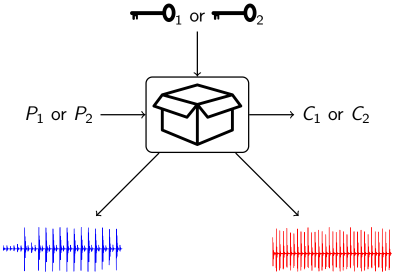
- Prior information about leaking points
  - Can reduce traces



Practical Evaluation Scenarios: White Box

In White Box:

- Prior information about leaking points
  - Can reduce traces
    - Can invert the covariance matrix (Hotelling's T^2-test)
    - High density



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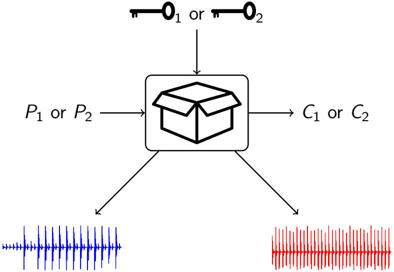
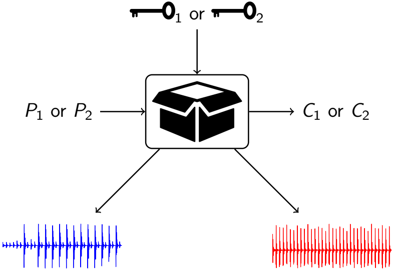


As a result:

- Smaller measurement period
- Easy interpretation of the confidence (no $\perp\!\!\!\perp$ assumption)

Practical Evaluation Scenarios: Black Box

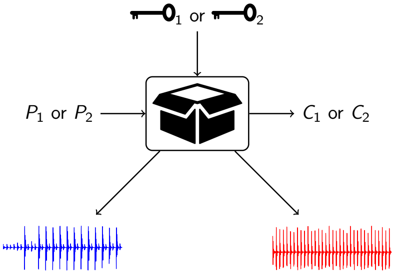
In Black Box:



Practical Evaluation Scenarios: Black Box

In Black Box:

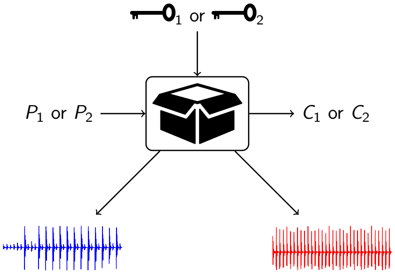
- No prior information about leaking points



Practical Evaluation Scenarios: Black Box

In Black Box:

- No prior information about leaking points
  - Can't reduce traces



Practical Evaluation Scenarios: Black Box

In Black Box:

- No prior information about leaking points
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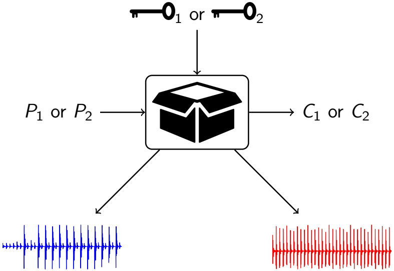
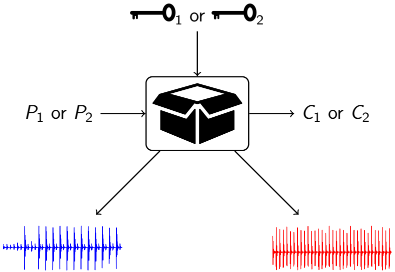
    - Can't always invert the covariance matrix



Practical Evaluation Scenarios: Black Box

In Black Box:

- No prior information about leaking points
  - Can't reduce traces
    - Can't always invert the covariance matrix
    - Fixed density



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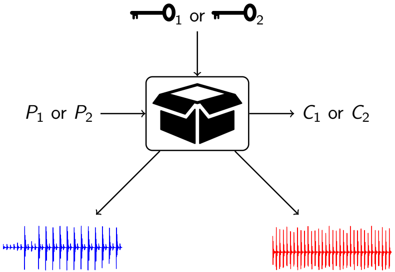

As a result:

- Possibly larger measurement period

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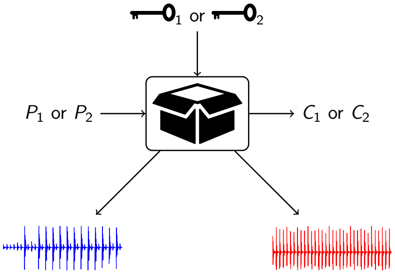

As a result:

- Possibly larger measurement period
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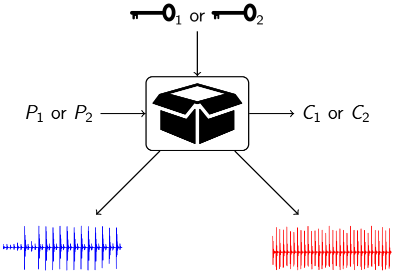

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As a result:

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- Independent assumption needed
  - Heuristic required for confidence level interpretation:
    - TVLA: too conservative
    - *D*-test: too optimistic

Content

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   - And sometimes reduction the measurement period
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Thanks !

Evaluation Hardness

github.com/obronchain/multituple_leakage_detection