J-DFA

A Novel Approach for Robust Differential Fault Analysis

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Attack Scenario

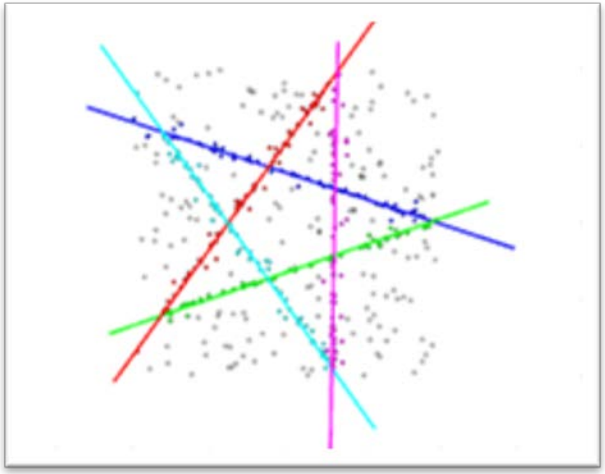
Most Differential Fault Analysis require some kind of knowledge by the attacker on the effect of the faults

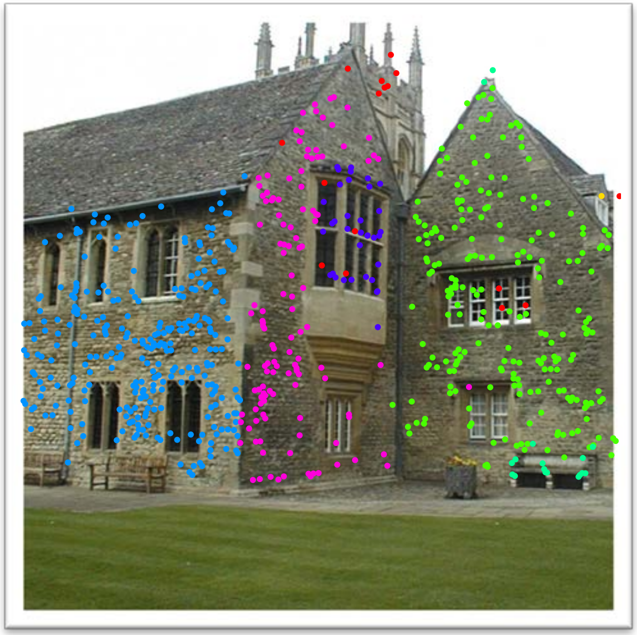
- Every fault provides information about the secret key, based on the model assumed a-priori by the attacker
- Discrepancies between model and experiments can lead to wrong solution (or no solution) for the key

This work: Application of a specific clustering technique with the purpose of softening the a-priori knowledge on the injection technique

J-Linkage

- Clustering technique that tackles the problem of fitting multiple models to data corrupted by noise and outliers
- Originally proposed for geometric model fitting in Computer Vision
  - homography estimation, plane fitting, motion segmentation

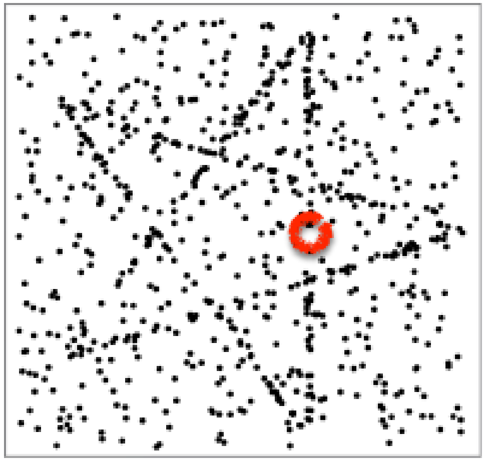




Properties of J-Linkage

- Based on conceptual data representation: each point is represented with the characteristic function of the set of models that fit the point
- A tailored agglomerative clustering is used to group points belonging to the same model
- Does not require prior specification of the number of models, nor it necessitates parameters tuning
- Robust to outliers

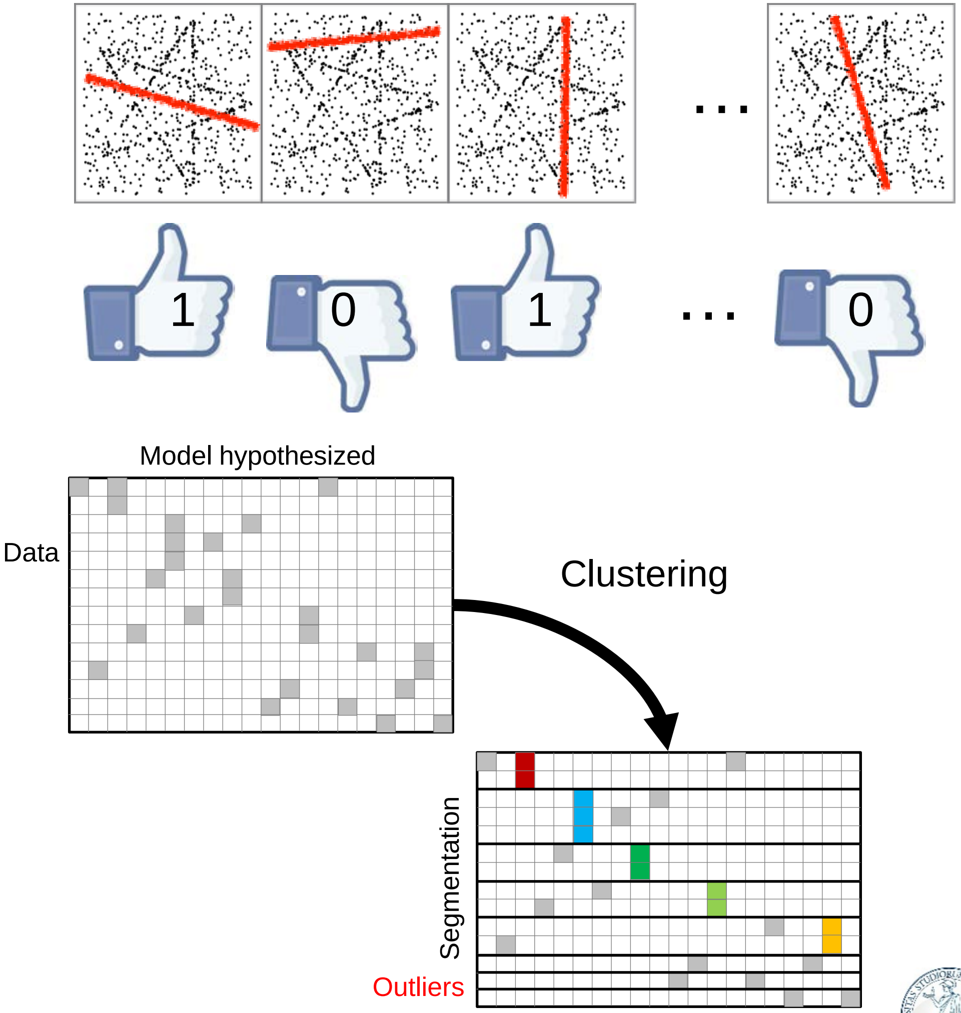
J-Linkage: geometric example



Model Hypothesis

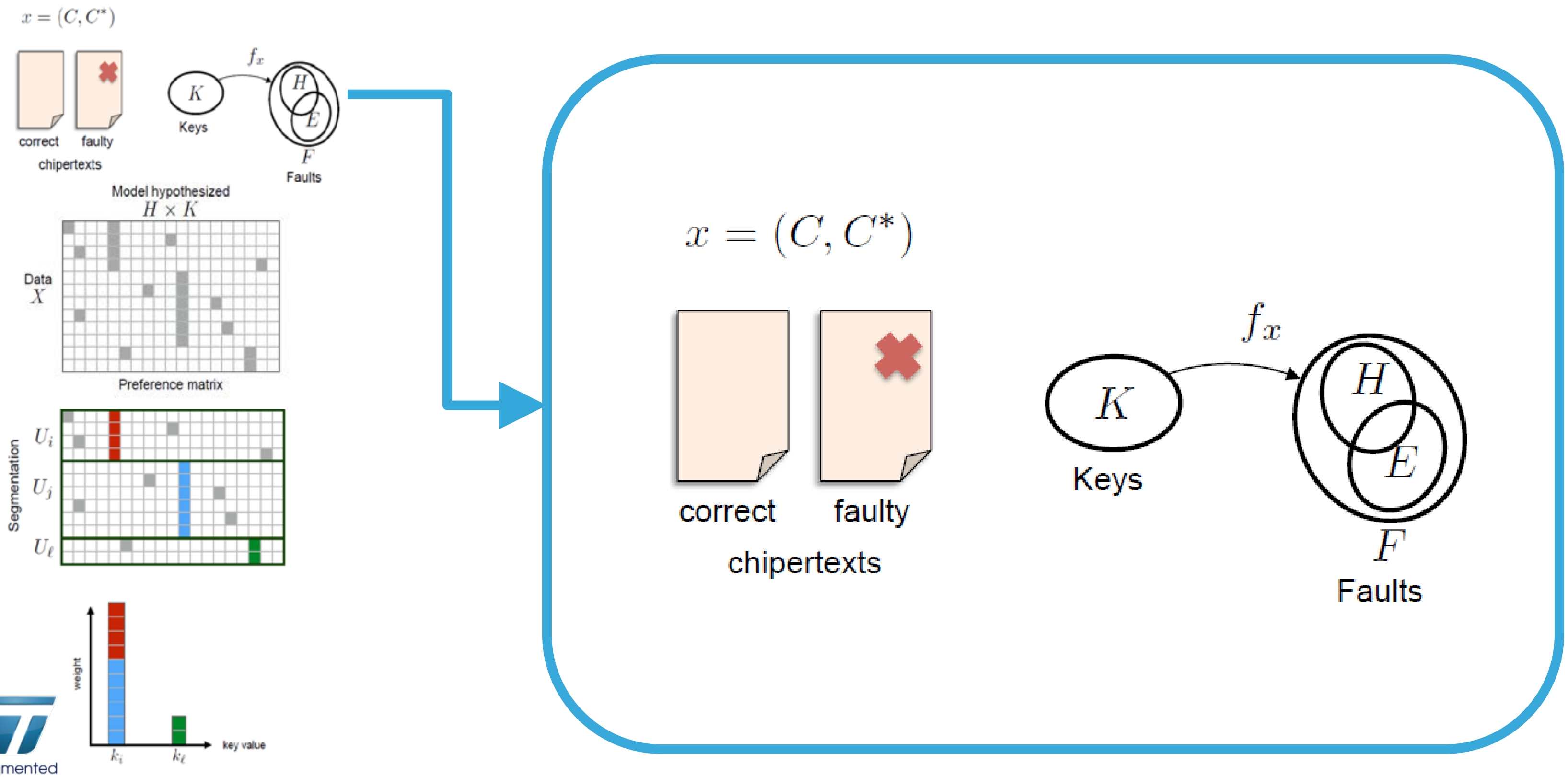
Points’ Preferences

Preference Matrix



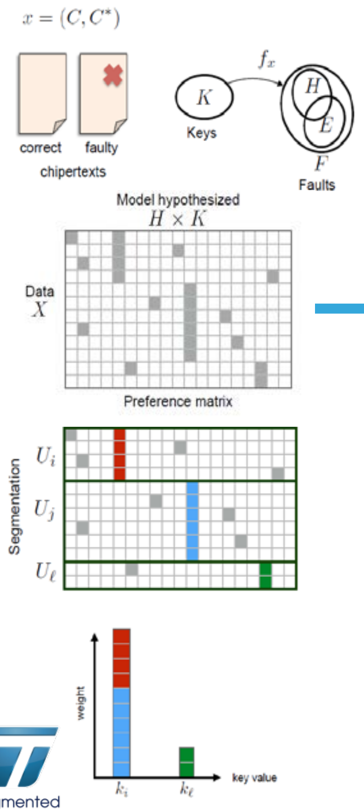
J-DFA: Data Mapping

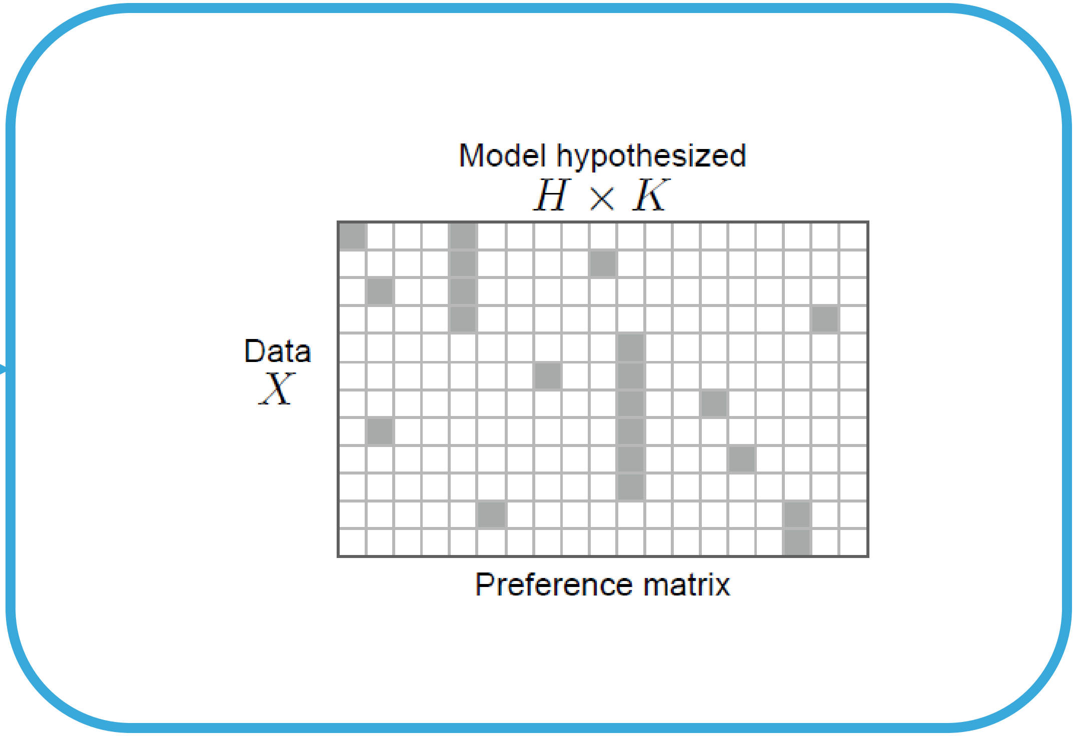
An experiment defines a map between possible key values and the set of possible faults.



J-DFA: Conceptual Representation

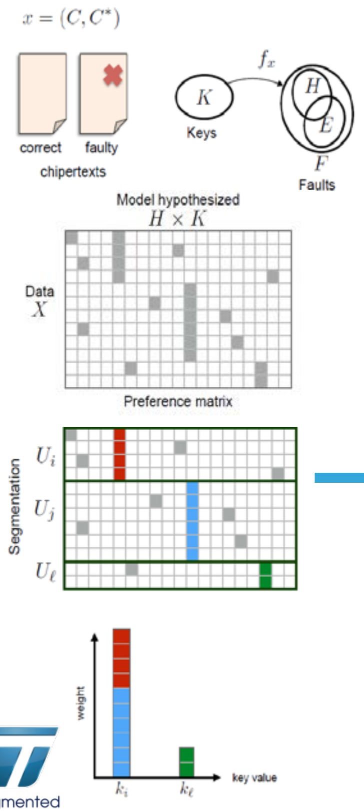
The preference matrix is built, representing every datum by the votes it grants to the set of putative models.

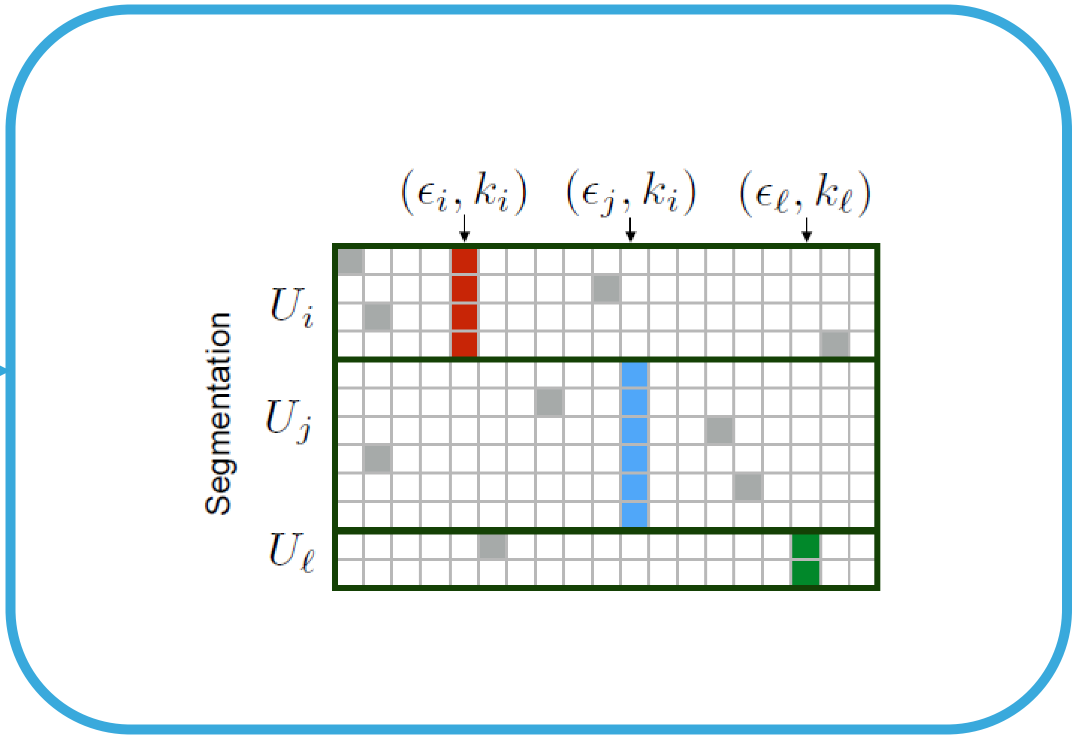




J-DFA: Clustering

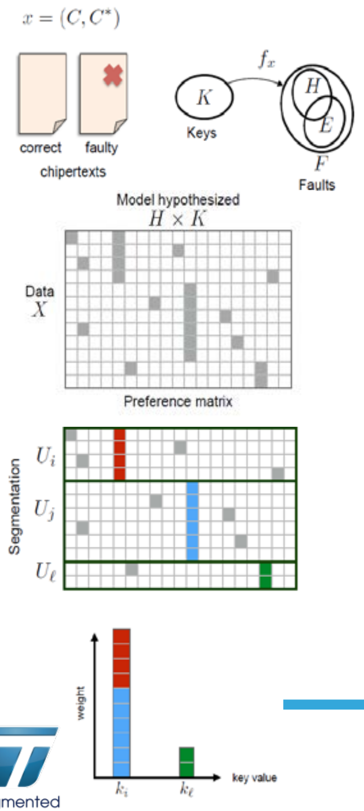
J-Linkage segments the preference matrix in clusters.
Most preferred models per cluster are extracted.
The same key may appear as preferred by several clusters.

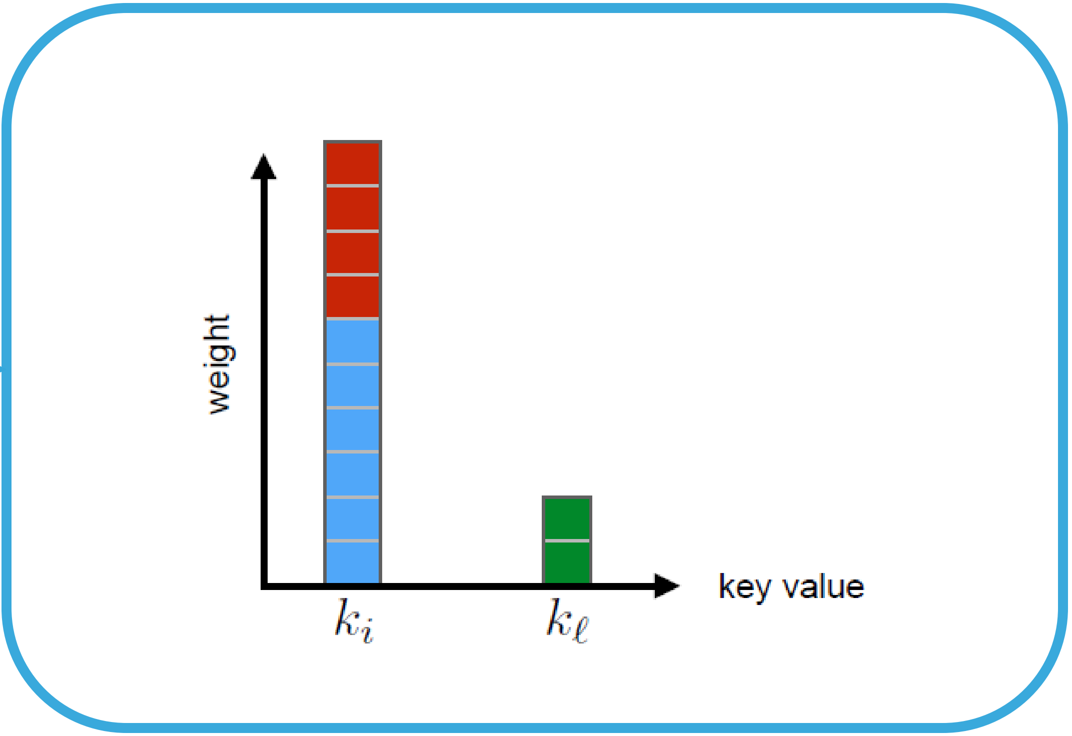




J-DFA: Ranking of the Keys

Votes are aggregated with respect to keys and the most preferred one is retained.





J-DFA: example

- DFA described in [Giraud] as a reference
  - Fault: one bit at the beginning of the last round of AES
    $E \in \{0x01, 0x02, 0x04, 0x08, 0x10, 0x20, 0x40, 0x80\}$
  - Experiment: a couple of correct and faulty ciphertexts
  - Data mapping: based on
    $\text{SubBytes}^{-1}(\mathrm{c} \oplus \mathrm{k}) \oplus \text{SubBytes}^{-1}(c^{*} \oplus \mathrm{k}) \in E$
- Among all the possible faults some can be filtered a-priori
  - When correct and faulty ciphertexts differ for more than a byte
- Experiments related to faults not included in the model are managed as outliers
  - They cannot be identified a-priori
  - They severely compromise the success of a classical DFA

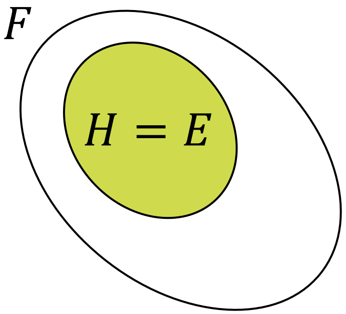
[Giraud] C. Giraud. *DFA on AES*. IACR Cryptology ePrint Archive, 2003.

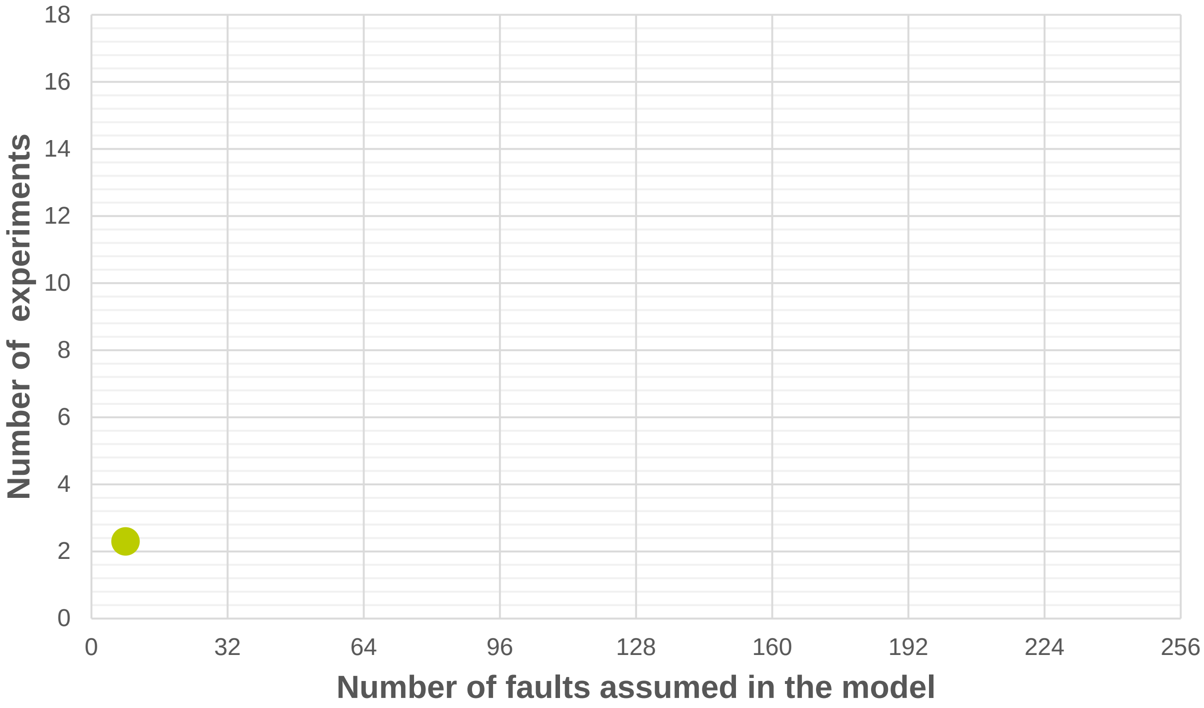
J-DFA with profiling

- Faults are generated through SW simulation
  - The set of possible fault effects E are defined at the beginning
- The assumed fault model H is exactly equal to E
  - The case when the attacker through profiling completely characterize the injection technique on the target device

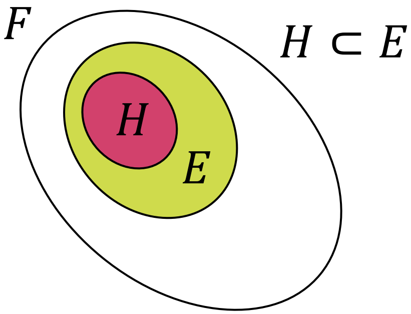
Possible Faults	**Average number of experiments to identify the correct byte of the key**
[Giraud]: $\|E\| = 8$	2.1
Only the least significant bit: $\|E\| = 1$	1.9
All but the most significant bit: $\|E\| = 127$	210,3

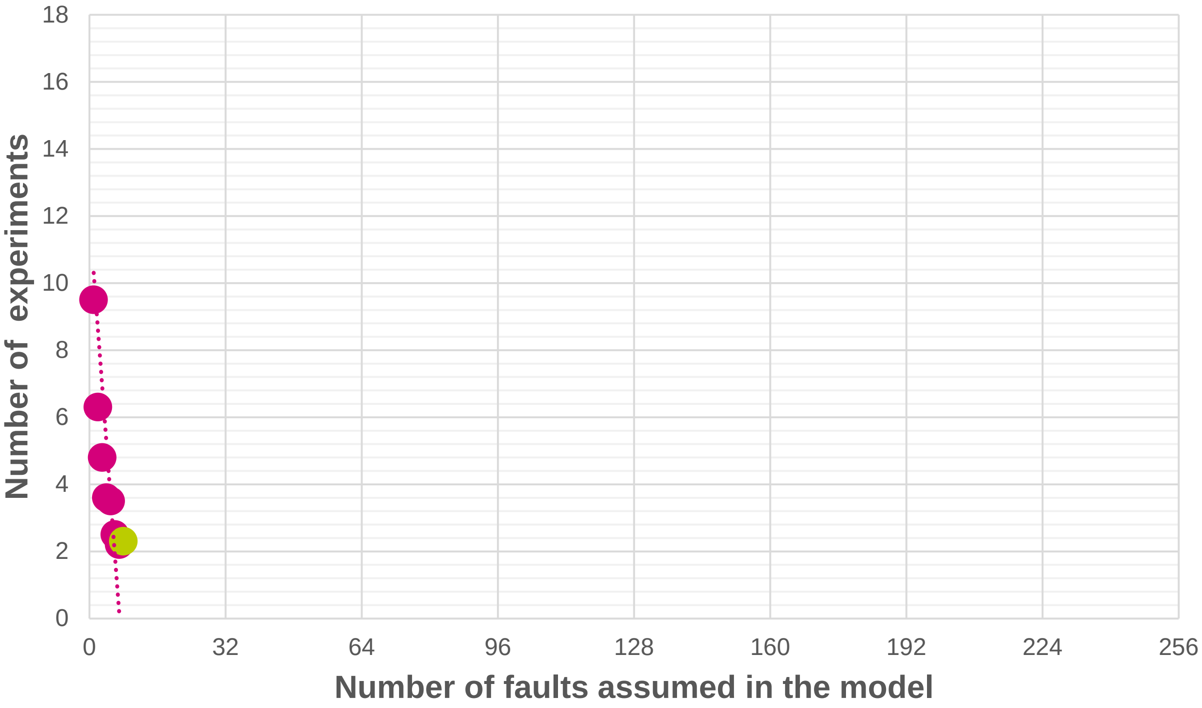
J-DFA with profiling



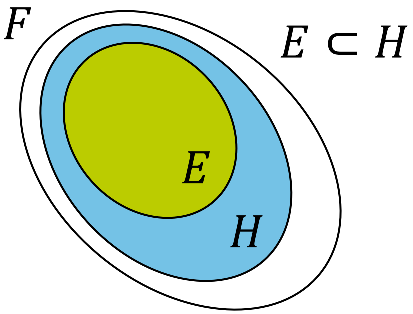


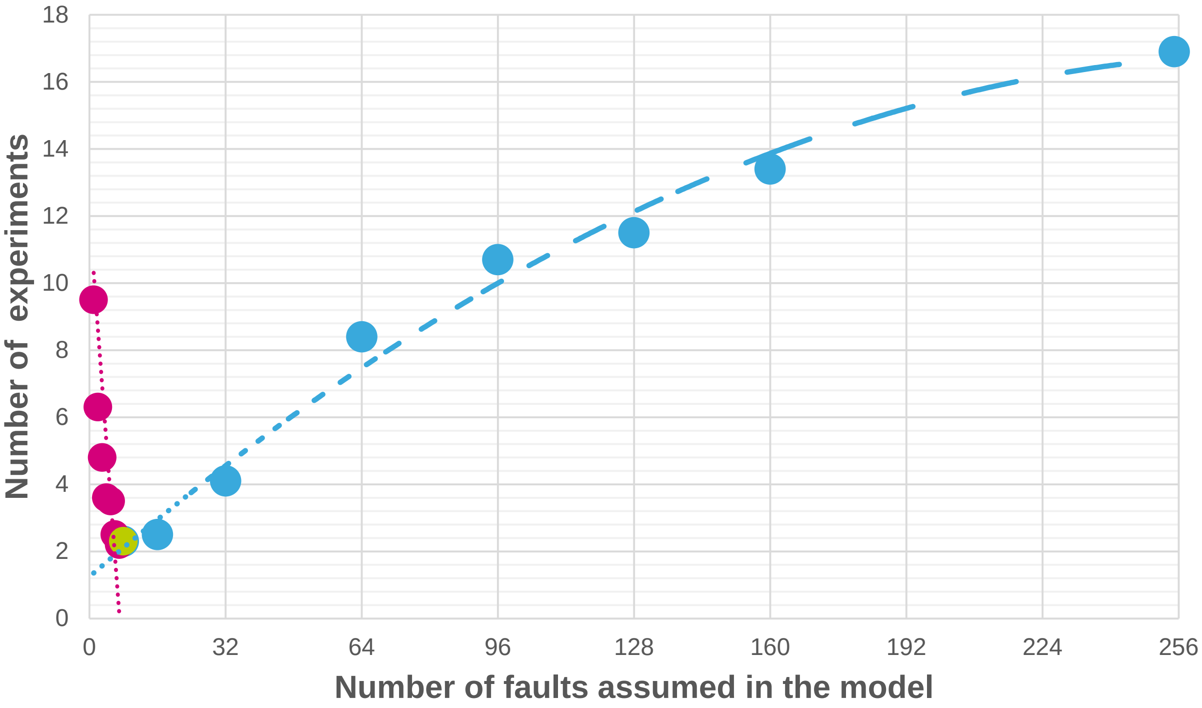
J-DFA without profiling





J-DFA without profiling





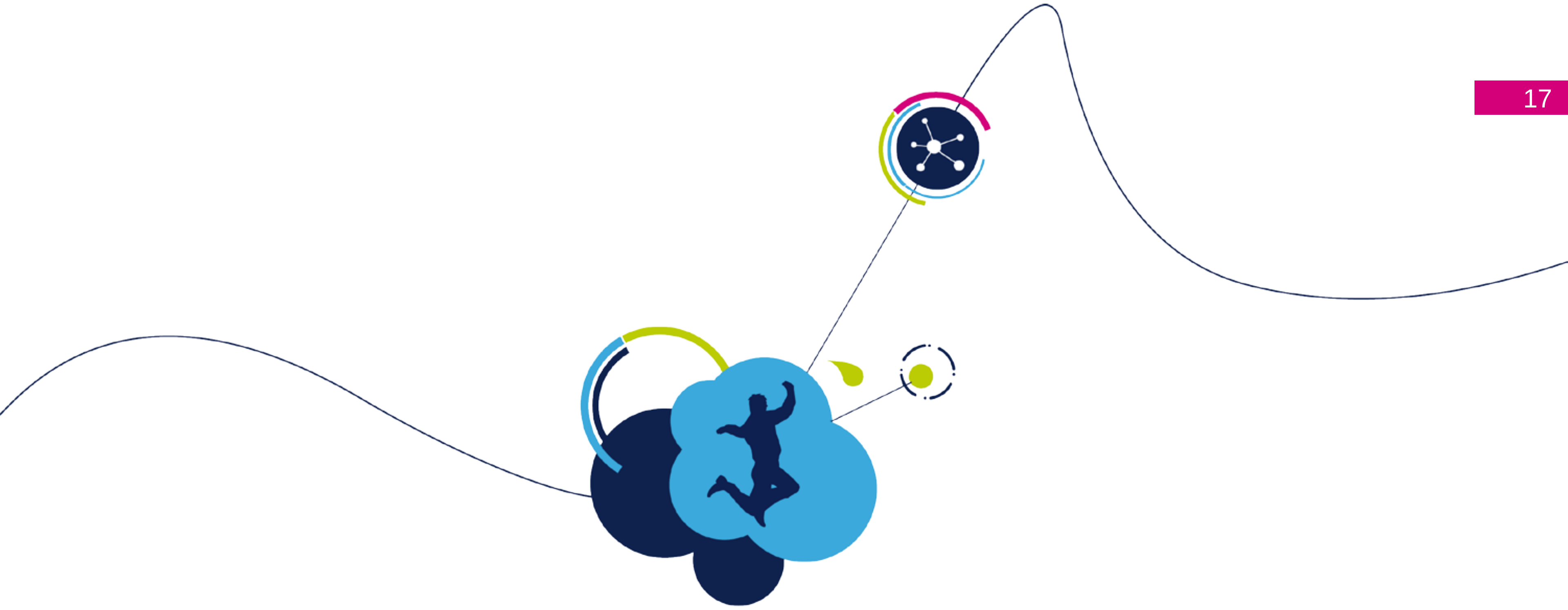
Working Conditions

- J-DFA works in case…
  - All the experiments fit in the model (which is limited to a subset)
    - It is assumed by many papers introducing new DFA attacks
  - Some of the experiments fit in the model
    - The others are managed as outliers
  - The model includes all the possible faults in a class
    - Differently from classical DFA

- J-DFA does not work in case…
  - None of the experiments fit in the model
    - Like any other approach that uses a wrong model

Conclusions

- J-DFA works!
  - Convenient tool to replicate classical DFA attacks
- J-DFA works even in case the experiments do not perfectly fit into the assumed model
  - Outliers are managed by J-linkage
  - The fault model can be extended up to an entire class of effects
- In principle J-DFA can be applied to any known DFA, by just adapting the "Data Mapping" stage
  - Still, the computational effort needs to be evaluated



Thank you