J-DFA
A Novel Approach for Robust Differential Fault Analysis

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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

Data

Model hypothesized

Clustering

Segmentation

Outliers
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-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
    \[ \text{SubBytes}^{-1}(c \oplus k) \oplus \text{SubBytes}^{-1}(c^* \oplus k) \in E \]

- 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

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

<table>
<thead>
<tr>
<th>Possible Faults</th>
<th>Average number of experiments to identify the correct byte of the key</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Giraud]: $</td>
<td>E</td>
</tr>
<tr>
<td>Only the least significant bit: $</td>
<td>E</td>
</tr>
<tr>
<td>All but the most significant bit: $</td>
<td>E</td>
</tr>
</tbody>
</table>
J-DFA with profiling

\[ H = E \]

Number of faults assumed in the model vs. Number of experiments.
J-DFA without profiling

\[ F \subset E \]

Number of experiments vs. Number of faults assumed in the model
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