



Maximizing the success of a side-channel attack

Annelie Heuser, Sylvain Guilley, Olivier Rioul

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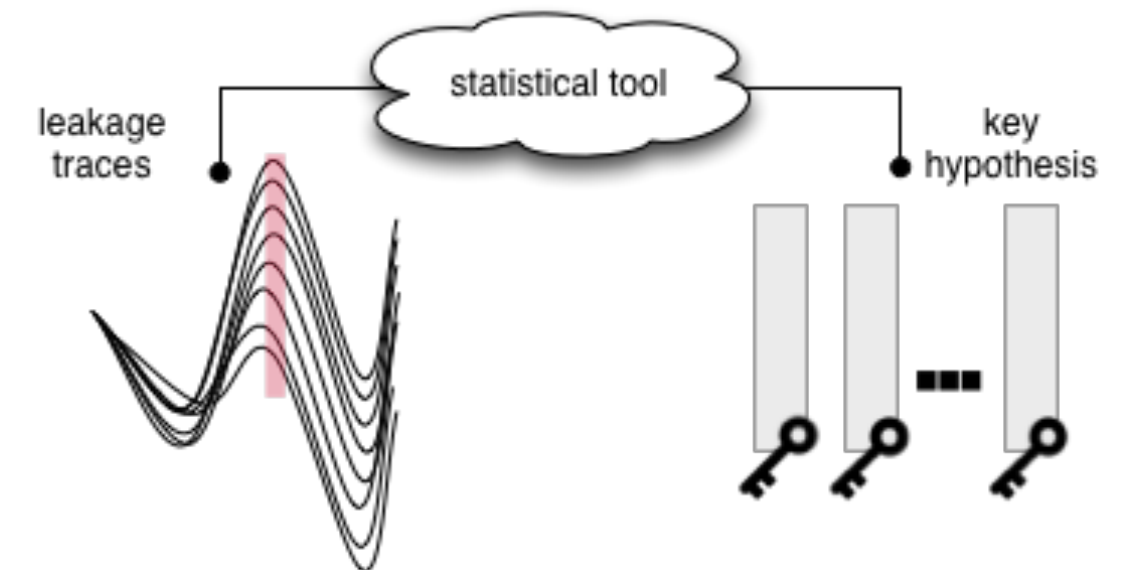
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State of the Art

- What distinguishes known distinguishers, in terms of distinctive features?
- Given a side-channel context, what is the best distinguisher amongst all known ones?

- Distinguishers were chosen as (arbitrary) **statistical tools** (correlation, difference of means, linear regression, etc.)
- [1] highlights that proposed distinguishers behave **equivalent** when using the same leakage model, only “statistical artifacts” can explain different behavior [2]
- The **estimation** of the statistical tools (esp. mutual information) is very crucial and effective on the success [3]



- [1] Doget, Prouff, Rivain, and Standaert, JCEN, 2011
- [2] Mangard, Oswald, and Standaert. IET, 2011
- [3] Prouff and Rivain, IJACT, 2010.
- [4] Heuser, Rioul, and Guilley, under submission

Side-channel analysis as a communication problem [4]

- Given a side-channel scenario, what is the best distinguisher, amongst all possible ones?

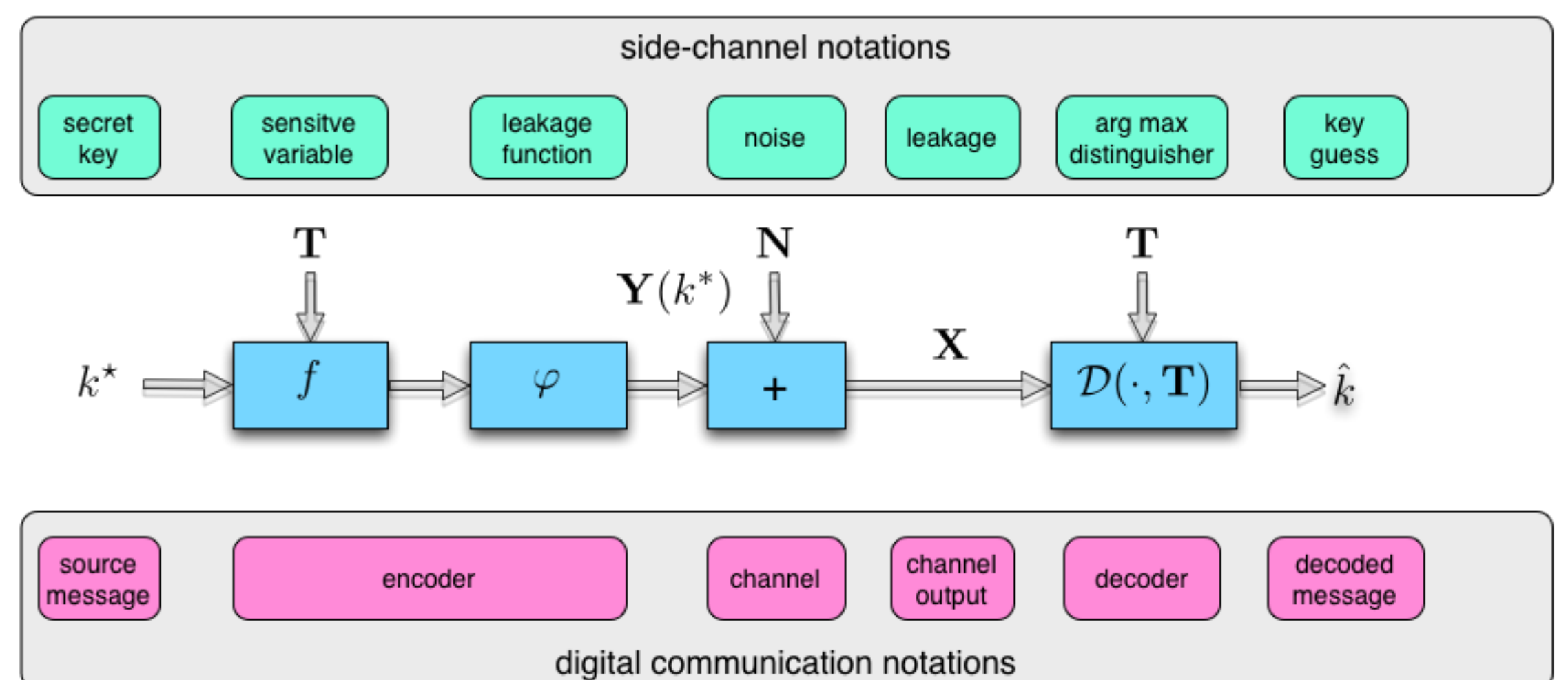
- Idea: Translate the problem of side-channel analysis into a problem of communication theory → derive **optimal distinguisher**: maximize the success rate

- Leakage model is known to the attacker (**Theorem 1**)

- Only statistical noise
- Optimal decoding rule $\arg \max_k (\mathbb{P}\{k\} \cdot p(\mathbf{x}|y(k)))$ (template attack, profiling is possible)
- The optimal distinguisher only depends on the noise distribution (e.g., Laplacian, uniform, Gaussian)

- Leakage model is partially unknown to the attacker (**Theorem 2**)

- Statistical and epistemic noise
- Leakage arises due to a weighted sum of bits, where the weights follow a normal distribution



Theorem 2: optimal distinguisher when the leakage model is partially unknown

Let $\mathbf{Y}_\alpha(k) = \sum_{j=1}^n \alpha_j [f(\mathbf{T}, k)]_j$, $\mathbf{Y}_j(k) = [f(\mathbf{T}, k)]_j$ and $\mathbf{X} = \sum_{j=1}^n \alpha_j [f(\mathbf{T}, k^*)]_j + N$ with $N \sim \mathcal{N}(0, \sigma^2)$. Assuming weights are independently deviating normally from the Hamming weight model, then the optimal distinguishing rule is

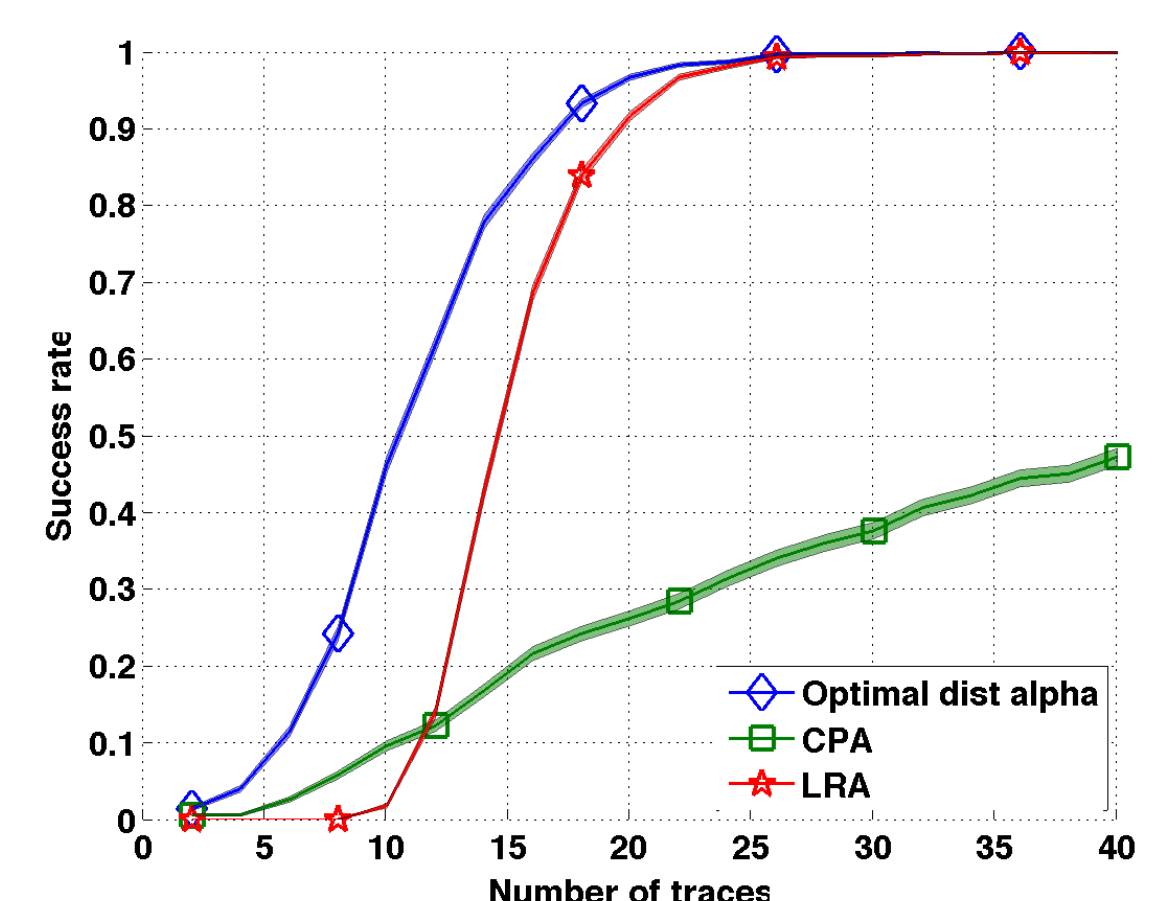
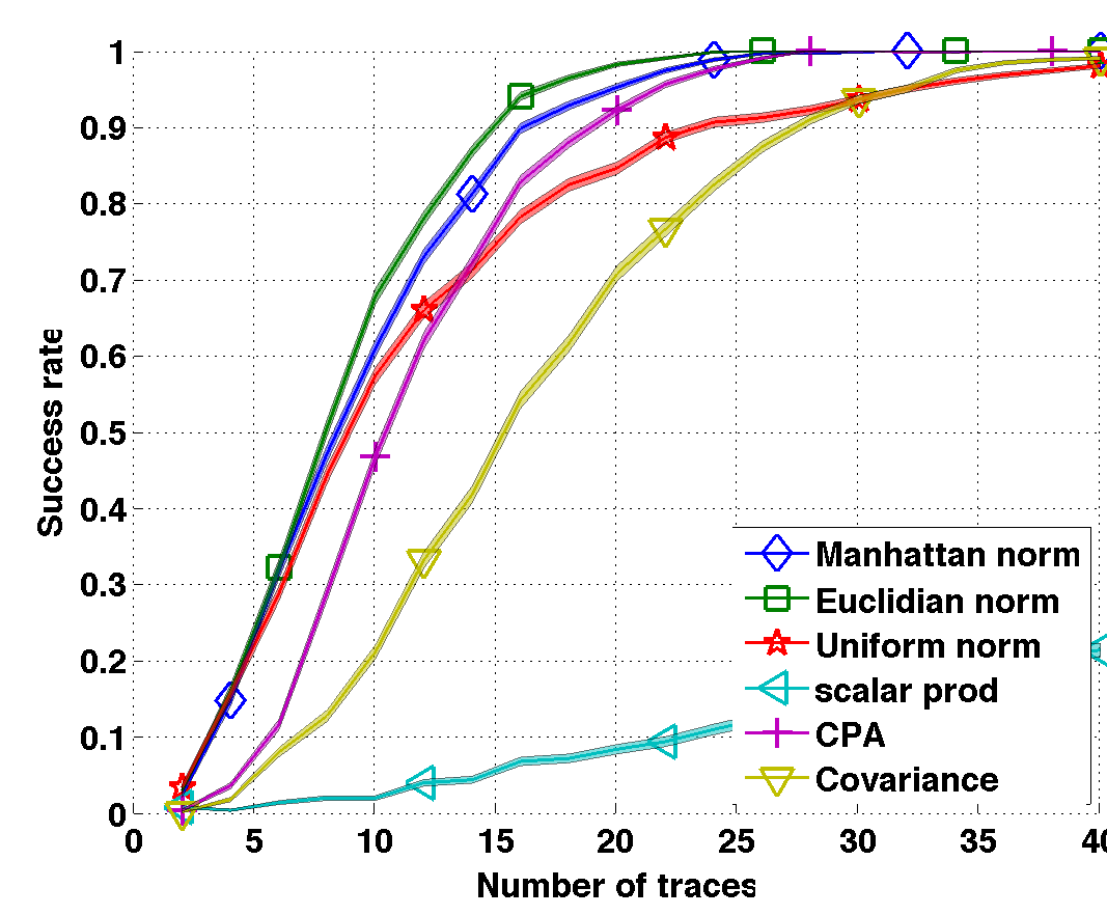
$$\mathcal{D}^{\alpha, G}(\mathbf{x}, \mathbf{t}) = \arg \max_k (\gamma \langle \mathbf{x} | \mathbf{y}(k) \rangle + 1)^t \cdot (\gamma Z(k) + I)^{-1} \cdot (\gamma \langle \mathbf{x} | \mathbf{y}(k) \rangle + 1) - \sigma_\alpha^2 \ln \det(\gamma Z(k) + I),$$

where $\gamma = \frac{\sigma_\alpha^2}{\sigma^2}$ is the **epistemic-to-stochastic-noise-ratio (ESNR)**.

Theorem 1: optimal distinguisher when the leakage model is known

If the leakage arises from $X = Y(k^*) + N$ with known leakage model $Y(k) = \varphi(f(k, \mathbf{T}))$ then the optimal distinguishing rule are

- Gaussian noise distribution: $\mathcal{D}_{opt}^{M, G}(\mathbf{x}, \mathbf{t}) = \arg \max_k \langle \mathbf{x} | \mathbf{y}(k) \rangle - \frac{1}{2} \|\mathbf{y}(k)\|_2^2$,
- Uniform noise distribution: $\mathcal{D}_{opt}^{M, U}(\mathbf{x}, \mathbf{t}) = \arg \max_k -\|\mathbf{x} - \mathbf{y}(k)\|_\infty$,
- Laplace noise distribution: $\mathcal{D}_{opt}^{M, L}(\mathbf{x}, \mathbf{t}) = \arg \max_k -\|\mathbf{x} - \mathbf{y}(k)\|_1$.



Known model

Partially unknown model

Our novel **optimal** distinguishers **outperform** all state-of-the-art distinguishers depending on statistical tools in terms of the **success rate!**

Correlation

Covariance

Linear regression