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Symmetric Cryptanalysis: the Foundation of Trust

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Symmetric Cryptanalysis: The Foundation of Trust

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informatics mathematics

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Outline

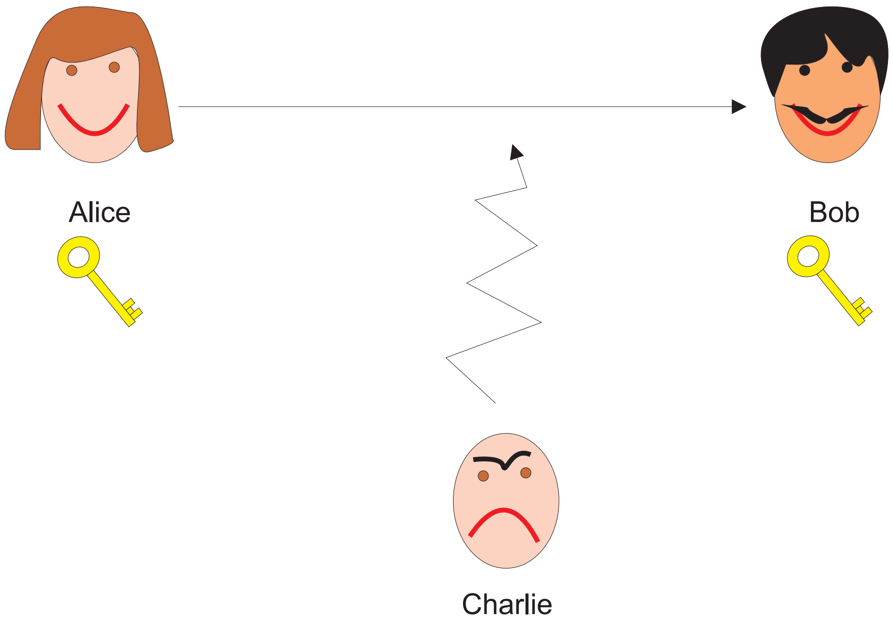
- Symmetric Cryptography
- Symmetric Cryptanalysis: Foundation of Trust
- Quantum Symmetric Cryptanalysis

Symmetric Cryptography

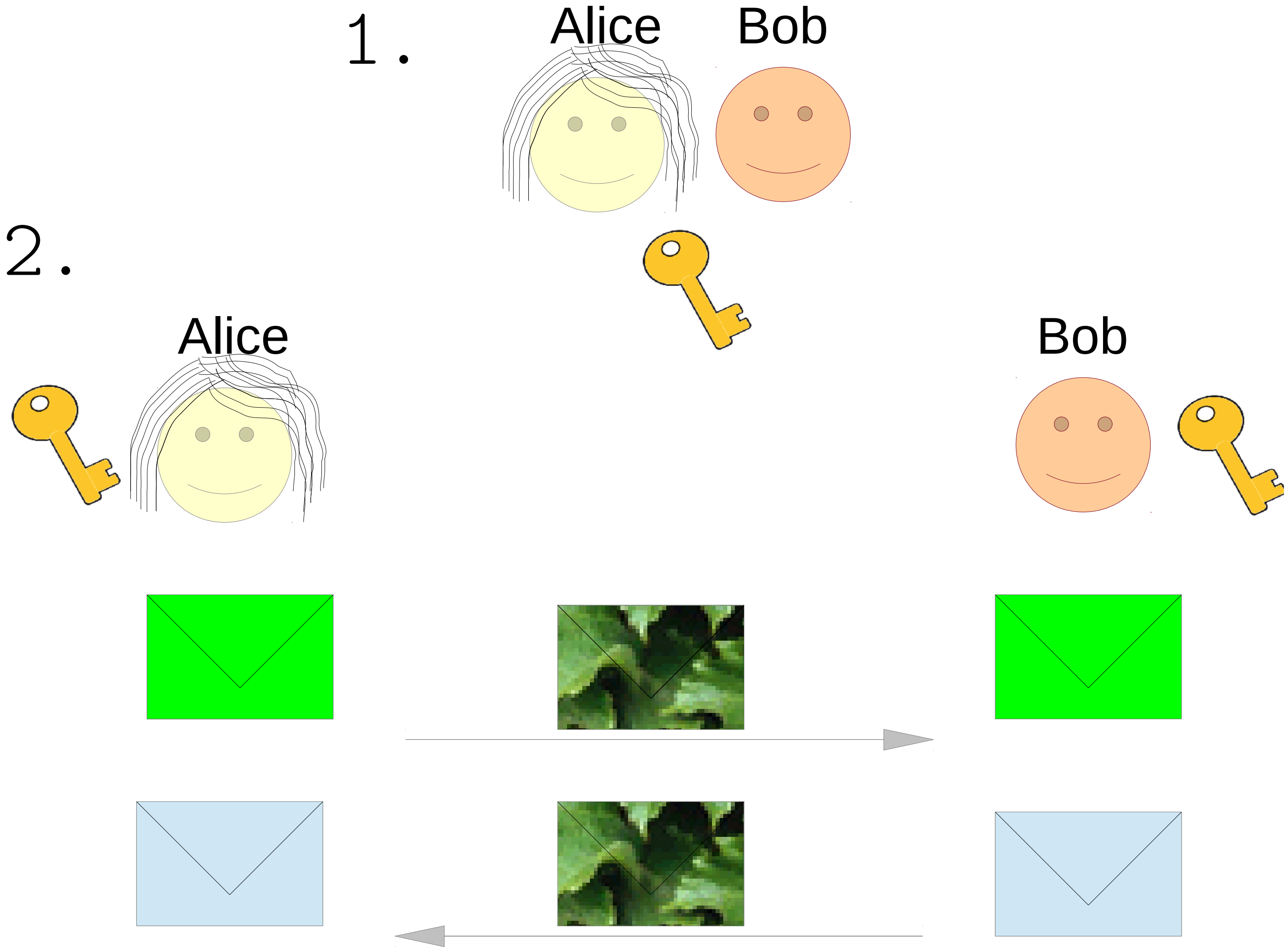
Cryptography

- Cryptography : hiding/protecting information, usually with the help of a key.

Symmetric cryptography and Asymmetric cryptography

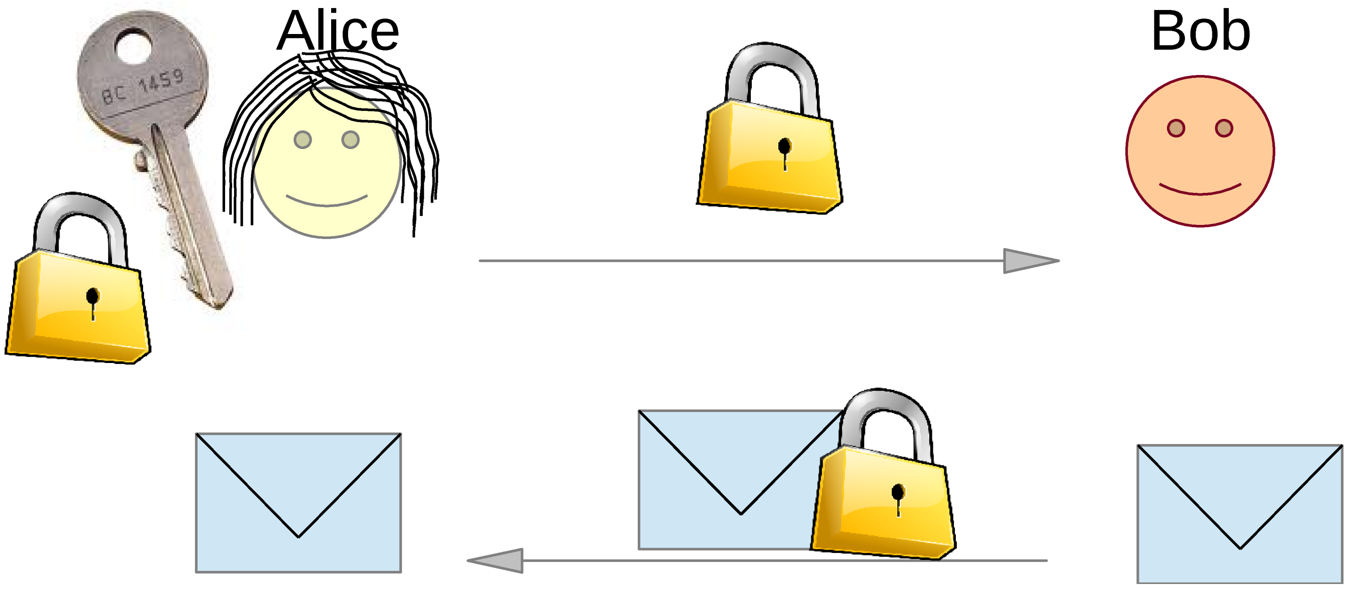


Symmetric Cryptography



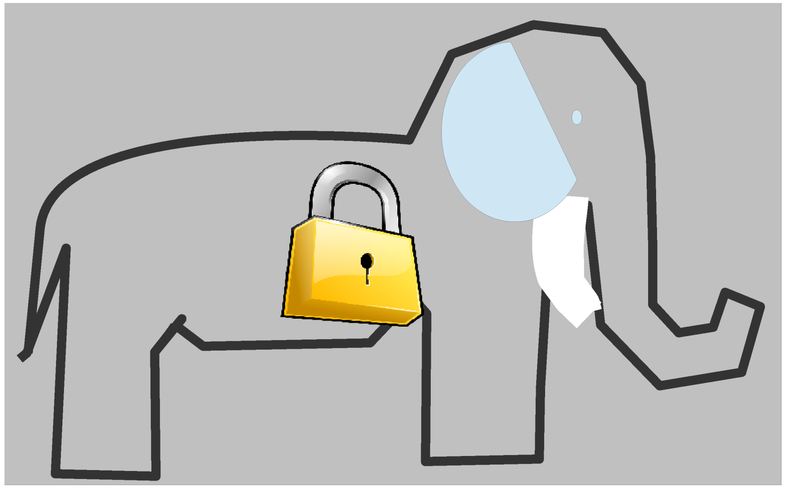
Asymmetric Cryptography

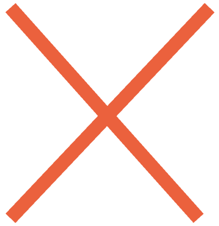
Without needing a previous meeting:

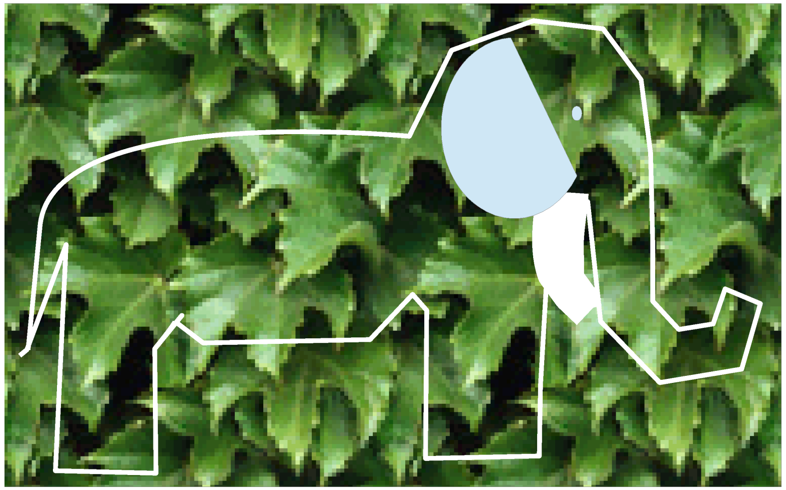


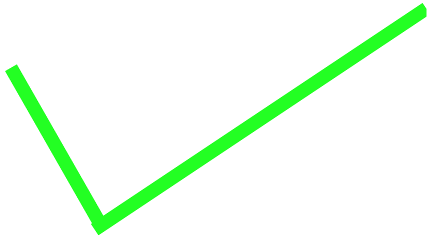
Asymmetric vs Symmetric Cryptography

Efficiency:









Asymmetric vs Symmetric Cryptography

Asymmetric:

- Advantage: No need of key exchange.
- Disadvantage: In "real life", "slow" and "big".

Symmetric:

- Disadvantage: Need of key exchange.
- Advantage: Performant, adapted to constrained environments.

$\Rightarrow$ Use asymmetric for key exchange, and next use symmetric!!.

Classical Cryptography

Enable secure communications even in the presence of malicious adversaries.

Asymmetric (e.g. RSA) *(no key exchange/computationally costly)*

Security based on well-known hard mathematical problems (e.g. factorization).

Symmetric (e.g. AES) *(key exchange needed/efficient)*

Ideal security defined by generic attacks ($2^{|K|}$).

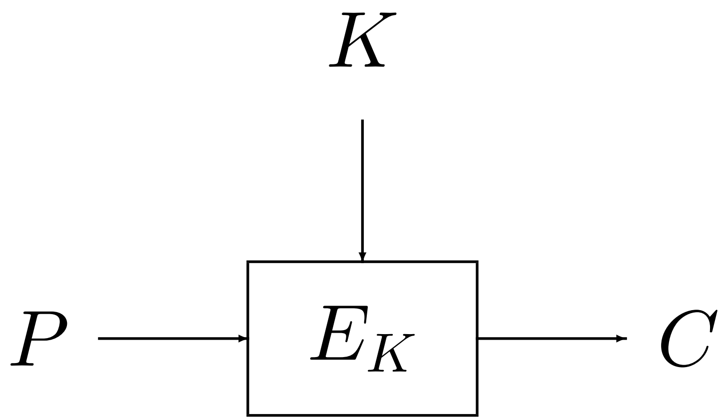
Need of continuous security evaluation (cryptanalysis).

⇒ Hybrid systems! (e.g. in SSH)

Symmetric primitives

- Block ciphers, (stream ciphers, hash functions..)

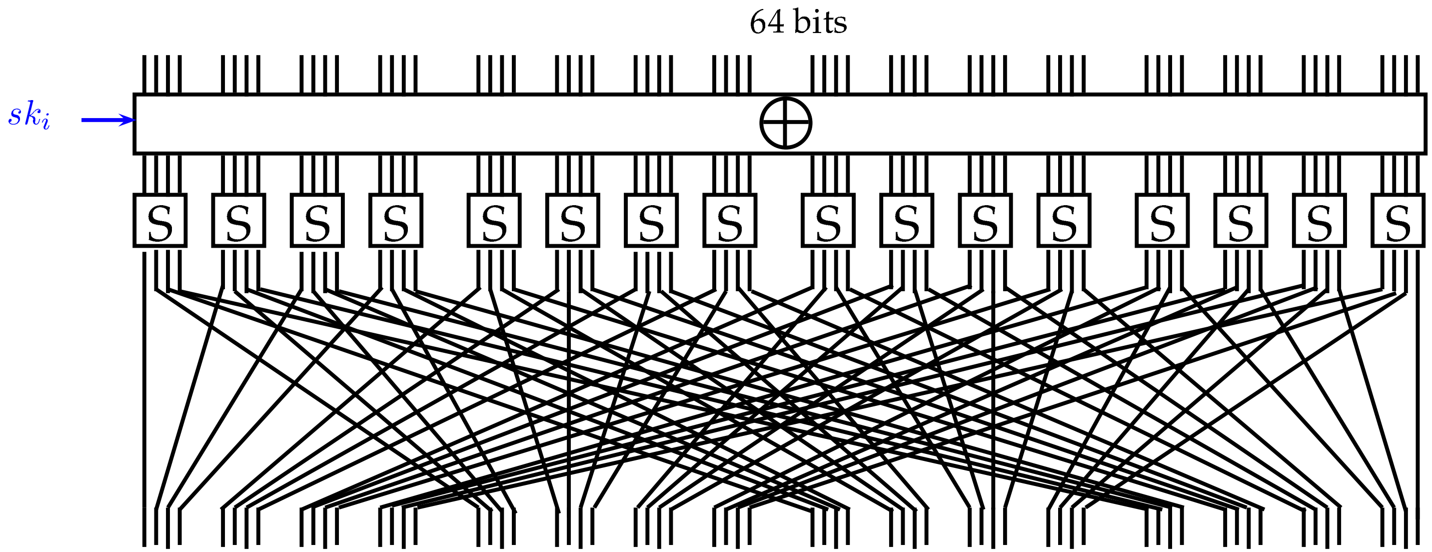
Message decomposed into blocks, each transformed by the same function E_K.



E_K is composed of a round transform repeated through several similar rounds.

Example: PRESENT [BKLPPRSV'07]

Block $n = 64$ bits, key 80 or 128 bits.



31 rounds + 1 key addition.

Generic Attacks on Ciphers

- Security provided by an ideal block cipher defined by the best generic attack:
  exhaustive search for the key in $2^{|K|}$.

- Recovering the key from a secure cipher must be infeasible:

  $\Rightarrow$ typical key sizes $|K| = 128$ to 256 bits.

Cryptanalysis: Foundation of Confidence

Any attack better than the generic one
is considered a "break".

- Proofs on symmetric primitives need to make unrealistic assumptions.
- We are often left with an empirical measure of the security: cryptanalysis.

Current scenario

- Competitions (AES, SHA-3, eSTREAM, CAESAR).
- New needs: lightweight, FHE-friendly, easy-masking.
  $\Rightarrow$ Many good proposals/candidates.

- How to choose?

- How to be ahead of possible weaknesses?

- How to keep on trusting the chosen ones?

Cryptanalysis: Foundation of Confidence

When can we consider a primitive as secure?

- A primitive is secure as far as no attack on it is known.
- The more we analyze a primitive without finding any weaknesses, the more reliable it is.

Design new attacks + improvement of existing ones:

- essential to keep on trusting the primitives,
- or to stop using the insecure ones!

On weakened versions

If no attack is found on a given cipher, what can we say about its robustness, security margin?

The security of a cipher is not a 1-bit information:

- Round-reduced attacks.
- Analysis of components.

$\Rightarrow$ determine and adapt the security margin.

On high complexities

When considering large keys, sometimes attacks breaking the ciphers might have a very high complexity far from practical *e.g.*. 2^{120} for a key of 128 bits.

Still dangerous because:

- Weak properties not expected by the designers.
- Experience shows us that attacks only get better.
- Other existing ciphers without the "ugly" properties.

- ▶ When determining the security margin: find the highest number of rounds reached.

Post-Quantum
Symmetric Cryptography

Post-Quantum Cryptography

Adversaries have access to **quantum computers.**

Asymmetric (e.g. RSA):

Shor's algorithm: Factorization in polynomial time

$\Rightarrow$ current systems not secure!

Solutions: lattice-based, code-based cryptography...

Symmetric (e.g. AES):

Grover's algorithm: Exhaustive search from $2^{|K|}$ to $2^{|K|/2}$.

Double the key length for equivalent ideal security.

We don't know much about cryptanalysis of current ciphers when having quantum computing available.

Post-Quantum Cryptography

Problem for present existing long-term secrets.
$\Rightarrow$ start using quantum-safe primitives NOW.

Important tasks:

- Conceive the cryptanalysis algorithms for evaluating the security of symmetric primitives in the P-Q world.
- Use them to evaluate and design symmetric primitives for the P-Q world.

Quantum Symmetric Cryptanalysis

Some recent results on Q-symmetric crytanalysis:

3-R Feistel [Kuwakado-Morii10], Even-Mansour [Kuwakado-Morii12], Mitm [Kaplan14], Related-Key [Roetteler-Steinwandt15], Diff-lin [Kaplan-Leurent-Leverrier-NP16], Simon's[Kaplan-Leurent-Leverrier-NP16], FX [Leander-May17], parallel multi-preim. [Banegas-Bernstein17], Multicollision [Hosoyamada-Sasaki-Xagawa17],
AEZ [Bonnetain17].

Final Conclusion

Symmetric (Quantum) Cryptanalysis

Better safe than sorry:

Lots of things to do !