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# Symmetric Cryptanalysis: the Foundation of Trust

María Naya-Plasencia

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# Symmetric Cryptanalysis: The Foundation of Trust

María Naya-Plasencia  
Inria, France

ERC project QUASYModo



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# Outline

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

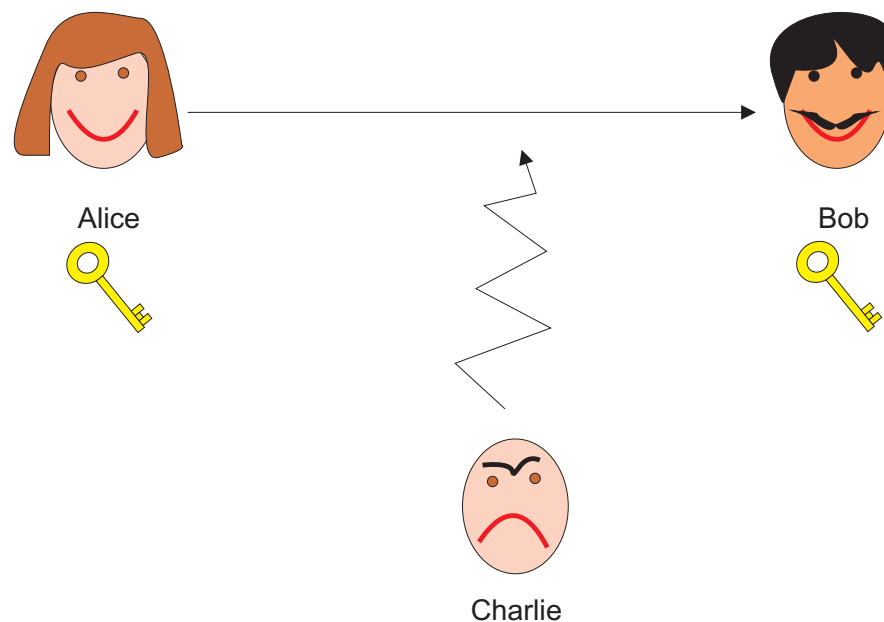
# Symmetric Cryptography

# Cryptography

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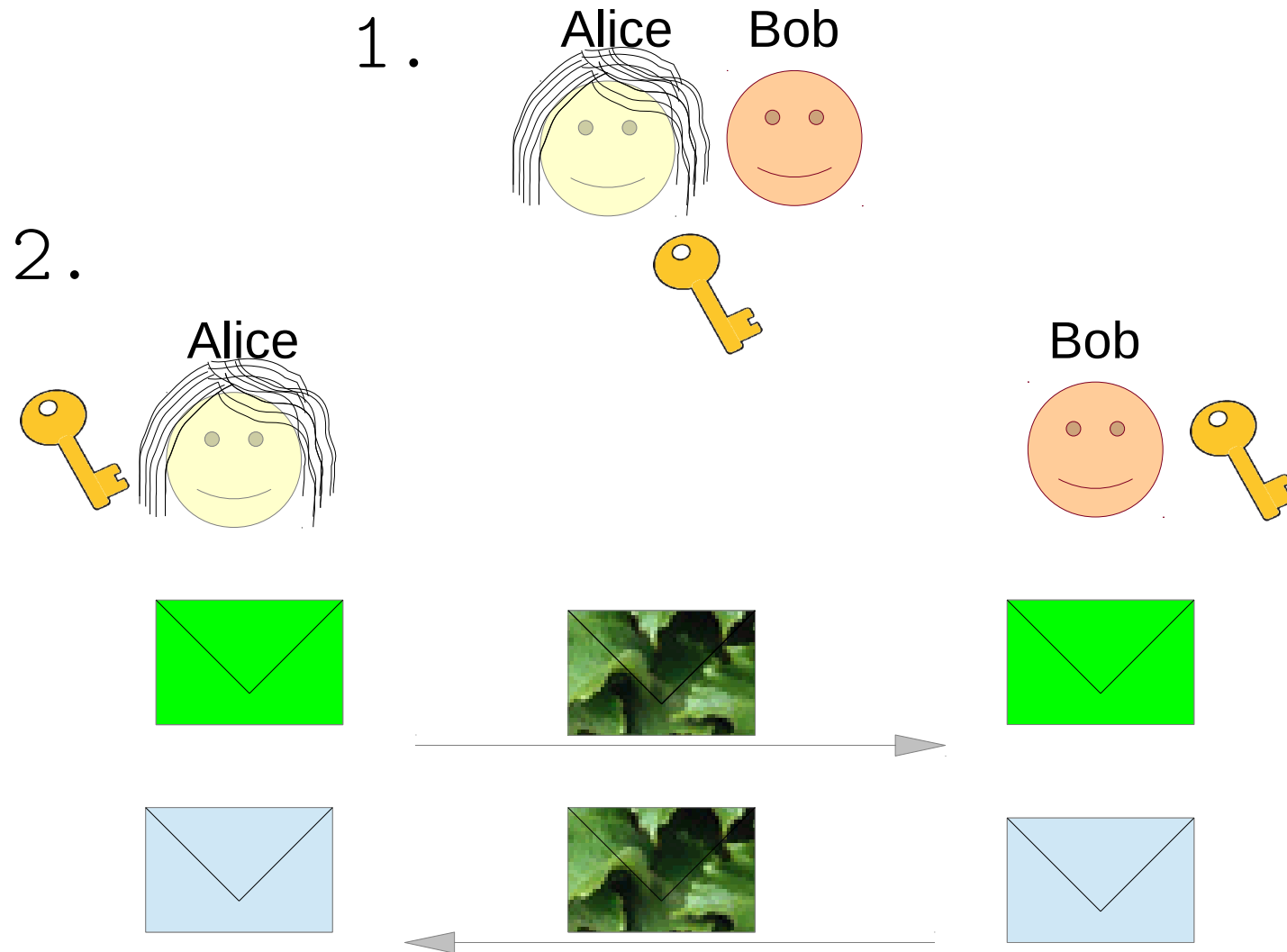
▶ Cryptography : hiding/protecting information, usually with the help of a key.

Symmetric cryptography and Asymmetric cryptography



# Symmetric Cryptography

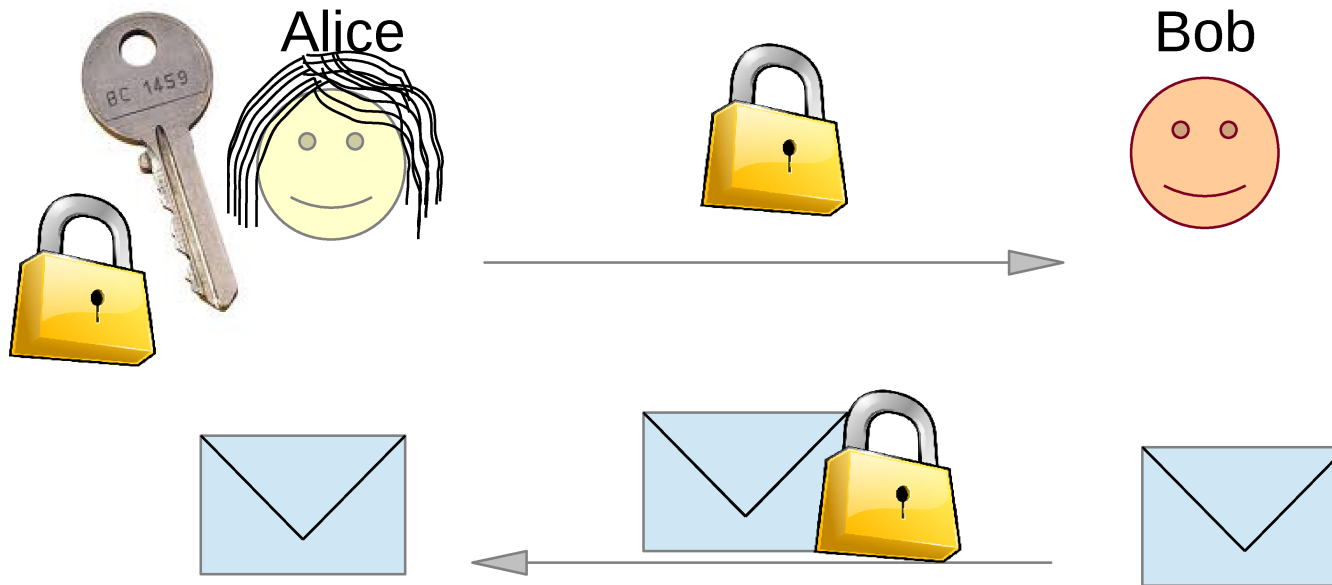
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# Asymmetric Cryptography

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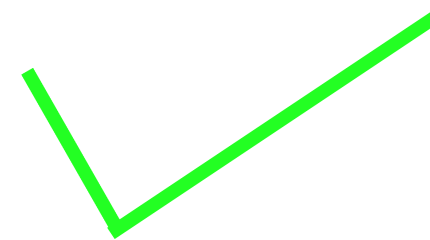
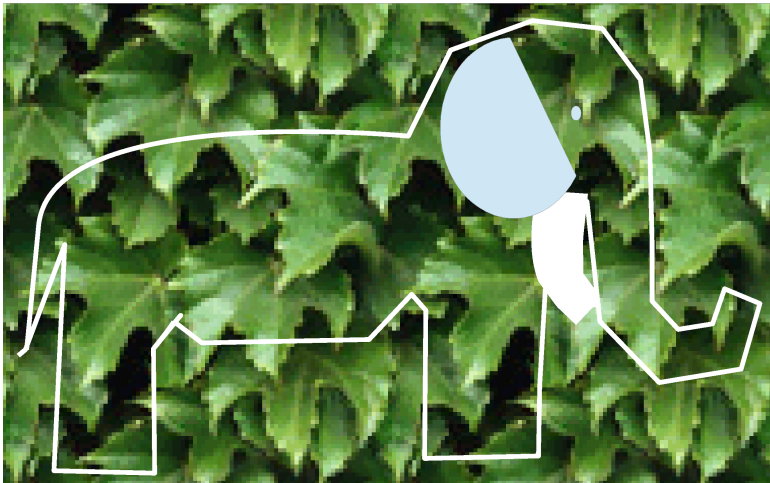
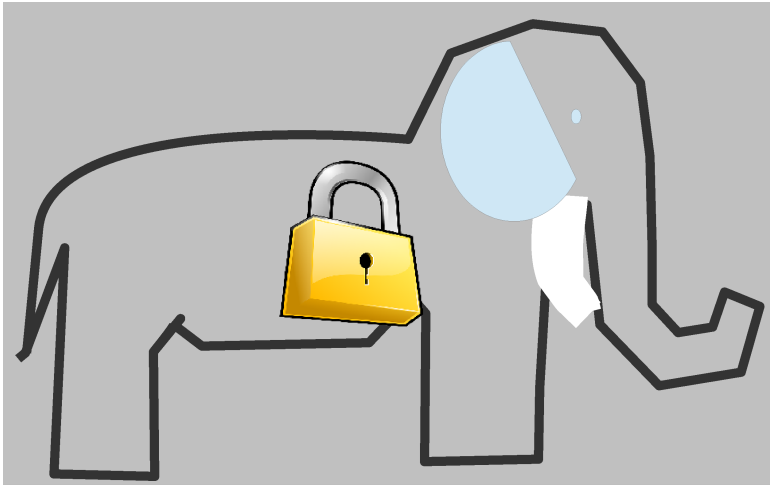
Without needing a previous meeting:



# Asymmetric vs Symmetric Cryptography

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Efficiency:





# Asymmetric vs Symmetric Cryptography

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## 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.

⇒ Use asymmetric for key exchange, and next use symmetric!!.

# Classical Cryptography

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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).

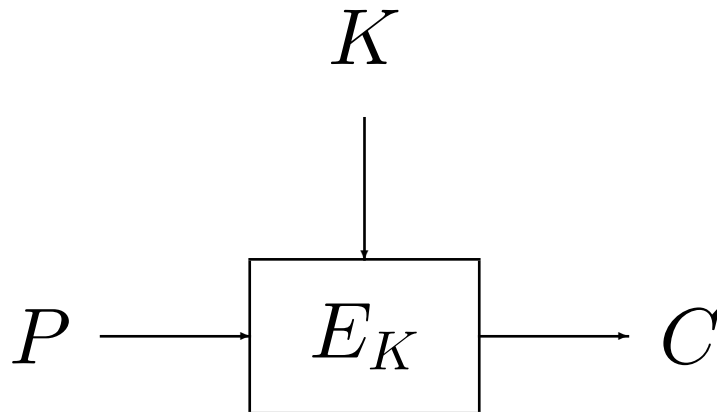
⇒ Hybrid systems! (e.g. in SSH)

# Symmetric primitives

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

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

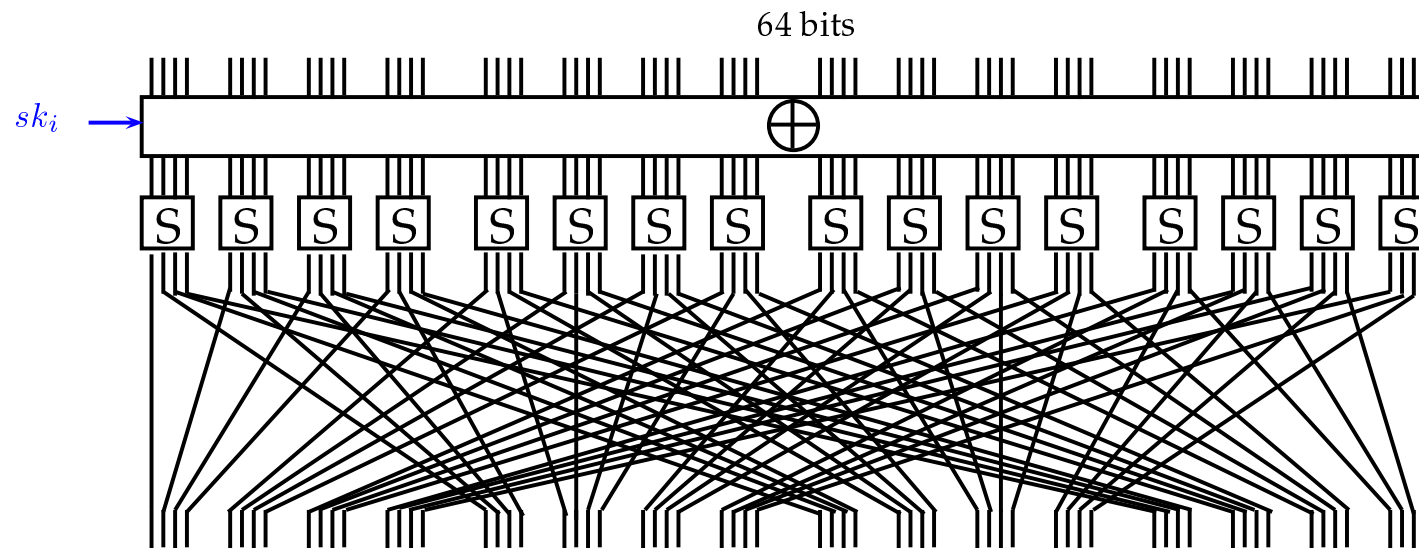


$E_K$  is composed of a round transform repeated through several similar rounds.

# Example: PRESENT [BKLP RSV'07]

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



31 rounds + 1 key addition.

# Generic Attacks on Ciphers

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- ▶ 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:  
⇒ typical key sizes  $|K| = 128$  to  $256$  bits.

# Cryptanalysis: Foundation of Confidence

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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

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- ▶ Competitions (AES, SHA-3, eSTREAM, CAESAR).
- ▶ New needs: lightweight, FHE-friendly, easy-masking.  
⇒ 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

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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

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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.
- ⇒ determine and adapt the security margin.

# On high complexities

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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

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Adversaries have access to **quantum computers**.

Asymmetric (e.g. RSA):

Shor's algorithm: Factorization in polynomial time

⇒ **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

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Problem for present existing long-term secrets.  
⇒ 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

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Some [recent results](#) on Q-symmetric cryptanalysis:

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

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Better safe than sorry:

Lots of things to do !