A QKD protocol and its integration into a software library

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Agenda

- Brief context introduction
- QKD: advantages and challenges (from CS PoV)
- Protocol design for unlimited distance and participants
- Formal proofs
- Randomness and security *(with Yoann PELET)*
- Implementing a user-friendly software library
- Conclusion: a video call secured by QKD

Context and personal introduction

- Thomas Prévost, CS engineer from Polytech
- PhD thesis, supervised by Bruno Martin (I3S)
- Co-supervised by Olivier Alibart

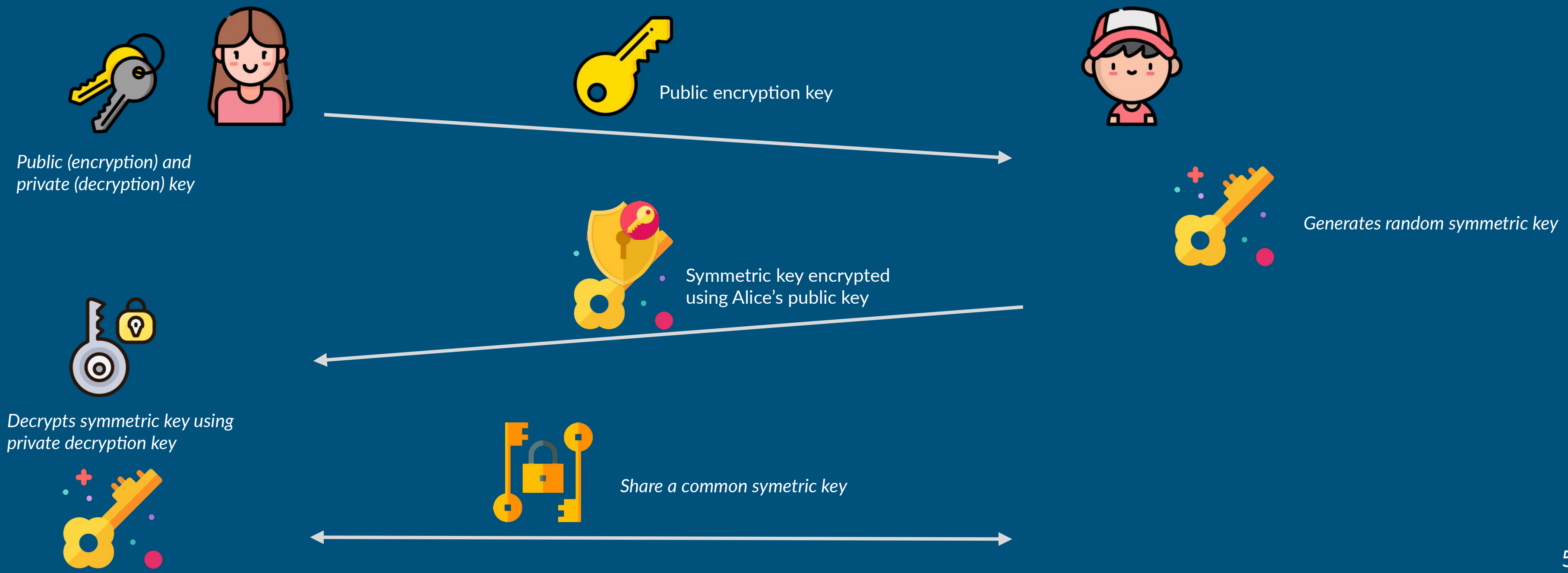
QKD: advantages (from CS PoV)

How to transmit a secret to someone I never met before ?

We should encrypt messages…

But how to transmit the encryption key between participants?

Current solution: public key cryptography



Public key drawbacks

- Symmetric key size limitation
- Potentially vulnerable to future attacks (for example quantum algorithms)

“Harvest now, decrypt later” attack

QKD advantages

- Unlimited key size
- Perfect forward-secrecy: encryption is **broken now or never**

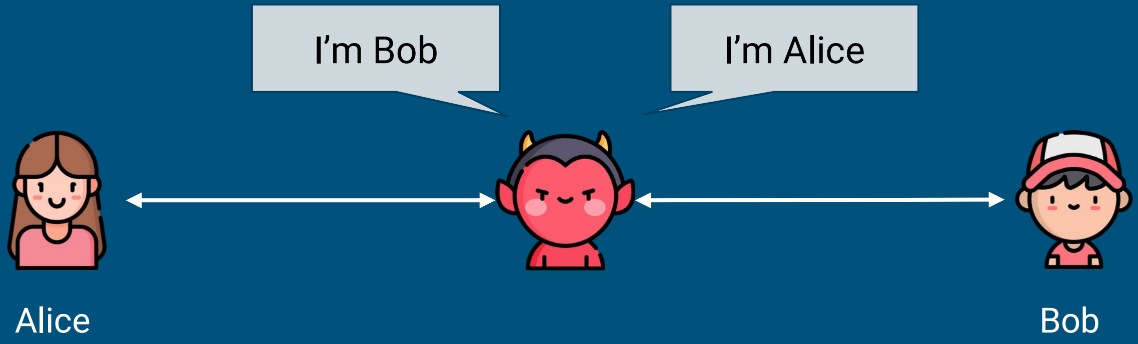
(from CS PoV)

Main QKD challenges

Very expensive: mostly suited for cross-datacenter communication

The authentication problem

QKD remains vulnerable to Man-In-The-Middle (MITM) attack



How can you be sure of someone’s identity?

Solution: use information you already know

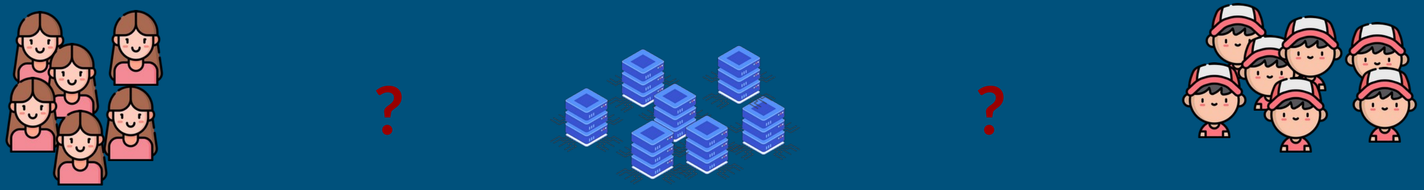
Solution: use authentication authority

Authentication

- There is no perfect authentication process as it exists for encryption
- You must adapt your method regarding your constraints
- Protocol are designed using some assumptions, these must be chosen properly

Protocol design: constraints

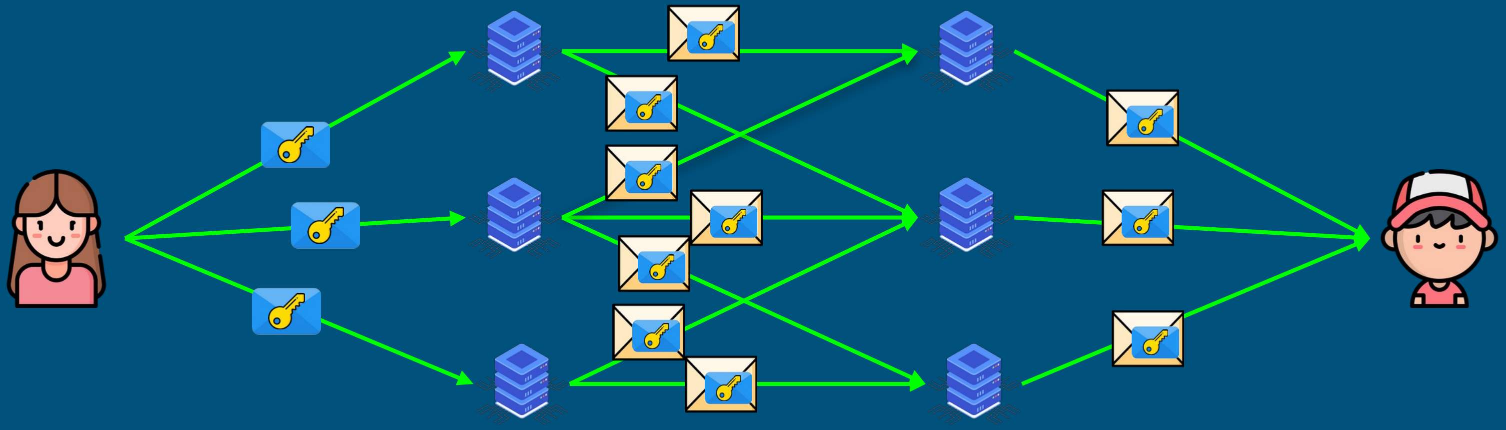
- From 2 to n x n users on the same channel



- Routing the secret through nodes in case of no direct QKD link

Introducing a new primitive: shared secrets

Our protocol: recursive secret sharing between intermediate nodes

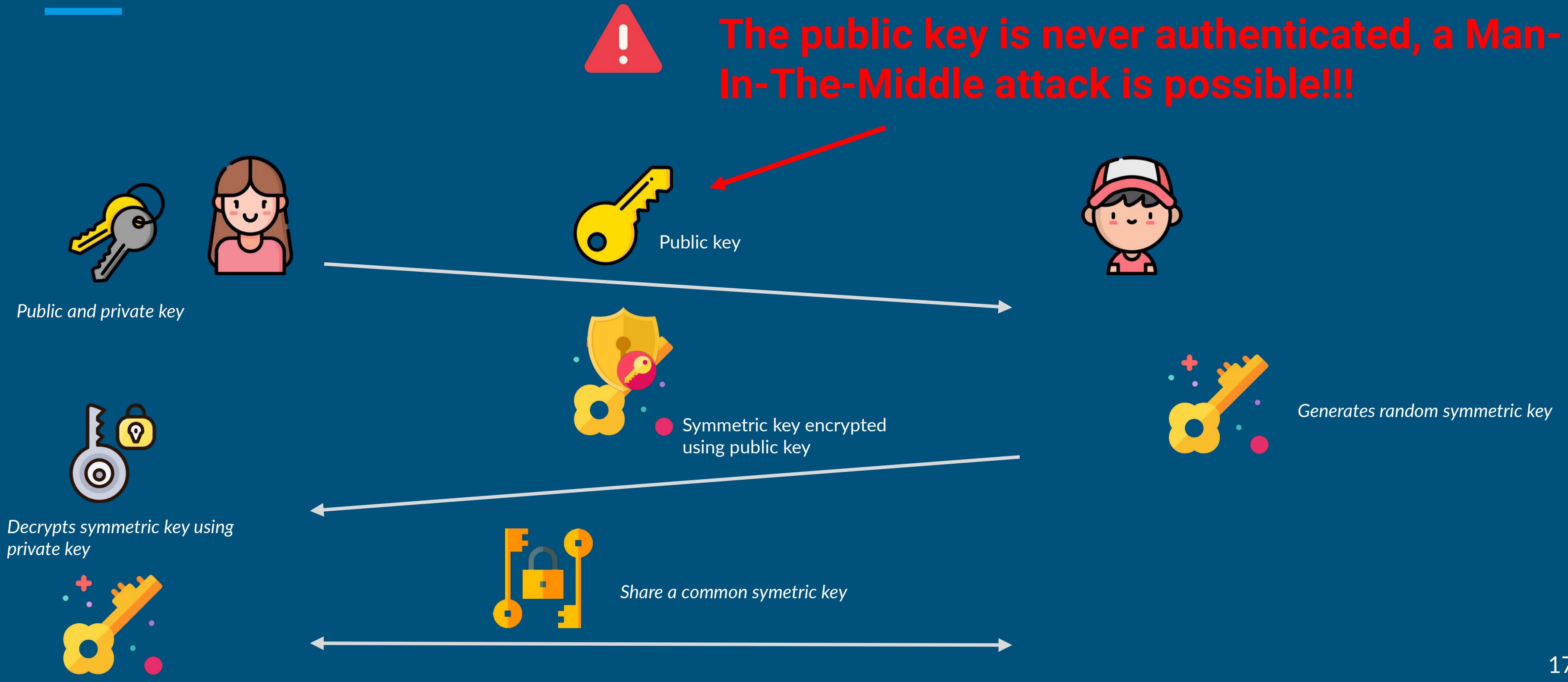


QKD independent secured channel

Key / secret

Shamir share, threshold = 51%

How to be sure that my protocol is flawless?



Solution: formal security provers

- Tries to infer all possible attacks over the protocol
- Possible replies:
  - unsafe (with the attack)
  - cannot be proven
  - safe
- Soundness: The prover cannot reply “safe” if an attack exists
- So we are **100% certain that our protocol is secure**!

Random generator assessment

Thanks to Yoann PELET

Randomness validation of symmetric key

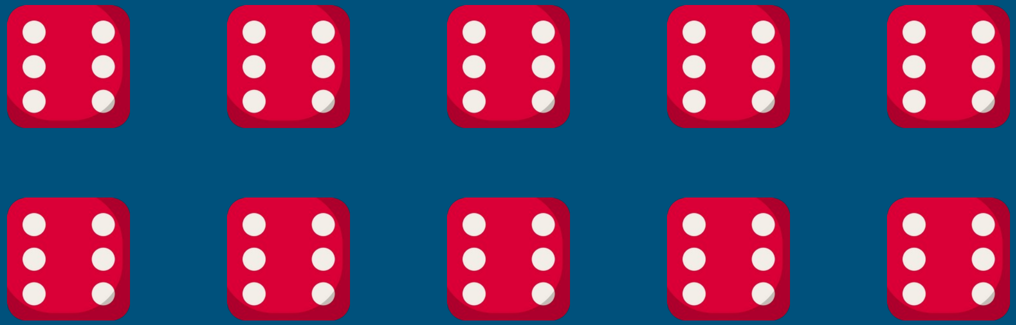
2 notions are hidden behind “randomness”:

- Initial source of entropy, should be unknown from the attacker (quantum entropy source is well suited).

- Final distribution, must “look like” random. This is what we are testing.

What is random? Let's play with dice

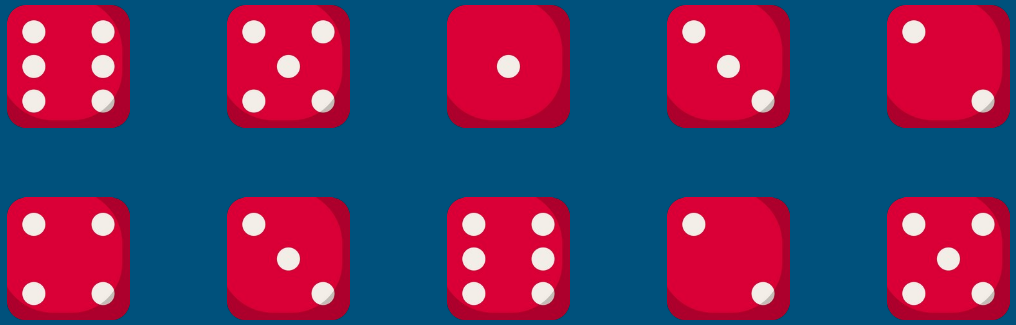
Let's throw 10 dice:



Would you trust me if I told you my dice were fair?

What is random? Let's play with dice

Restart the experiment



And now would you consider my dice random?

WHY?

Randomness distribution validation

- There is no way to prove that an output distribution satisfies randomness requirements with 100% certainty
- What we can do is “statistical tests” over a large range of data, and verify that the output bits “look random”

Randomness validation of QKD output bits

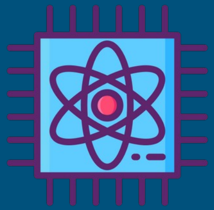
Does QKD generator validate statistical tests?

No

So how could we extract cryptographic keys?

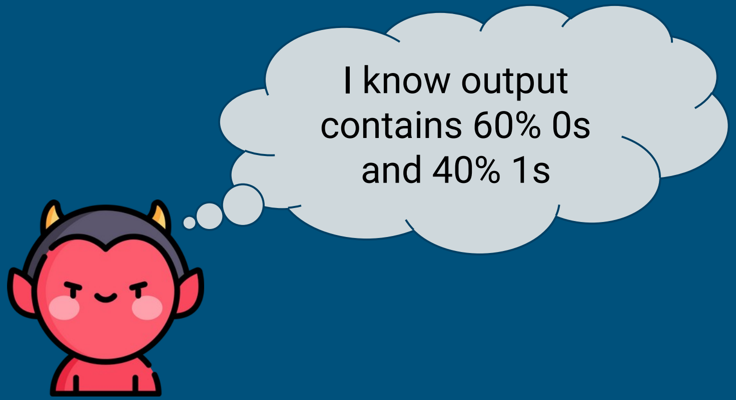
Thanks to Yoann PELET

Privacy Amplification and min-entropy



Quantum generator

n bits =
0 1 0 0 0 1 1 0 1 0



- **Privacy Amplification** is a deterministic algorithm that extract uniform distribution from output bits. It is run by both participants after QKD is finished.
- It can extract m < n random bits, due to attacker biasis knowledge. This is called **min-entropy**.

Randomness validation of PA output bits

Does Privacy Amplification generator validate statistical tests?

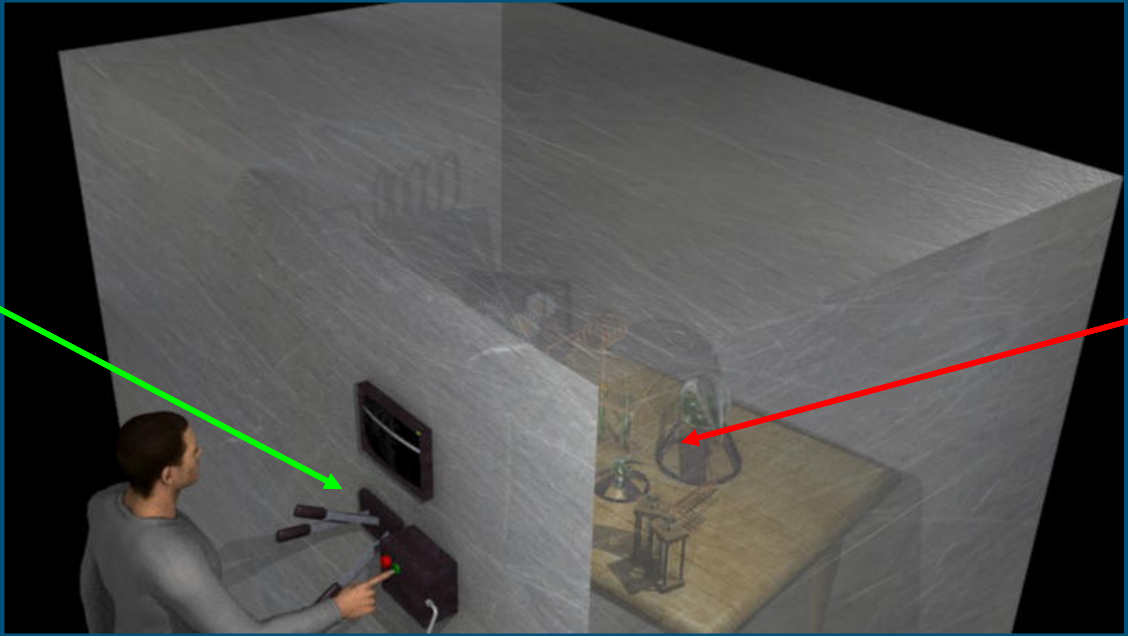
Yes

We can use the PA output bits as cryptographic keys

Implementing a user-friendly software library

A good encapsulation

Very easy for the final developer



Very complex mechanism

Implementing a user-friendly software library

- Layer over SSL/TLS (HTTPS)
- Backwards compatibility with classic HTTPS
- Followed ETSI GS QKD 014 v1.1.1
- Target: RFC (Request For Comments), ie Internet standard

Conclusion: a video call secured by QKD

Thanks

Do you have questions?