Quantum Communication

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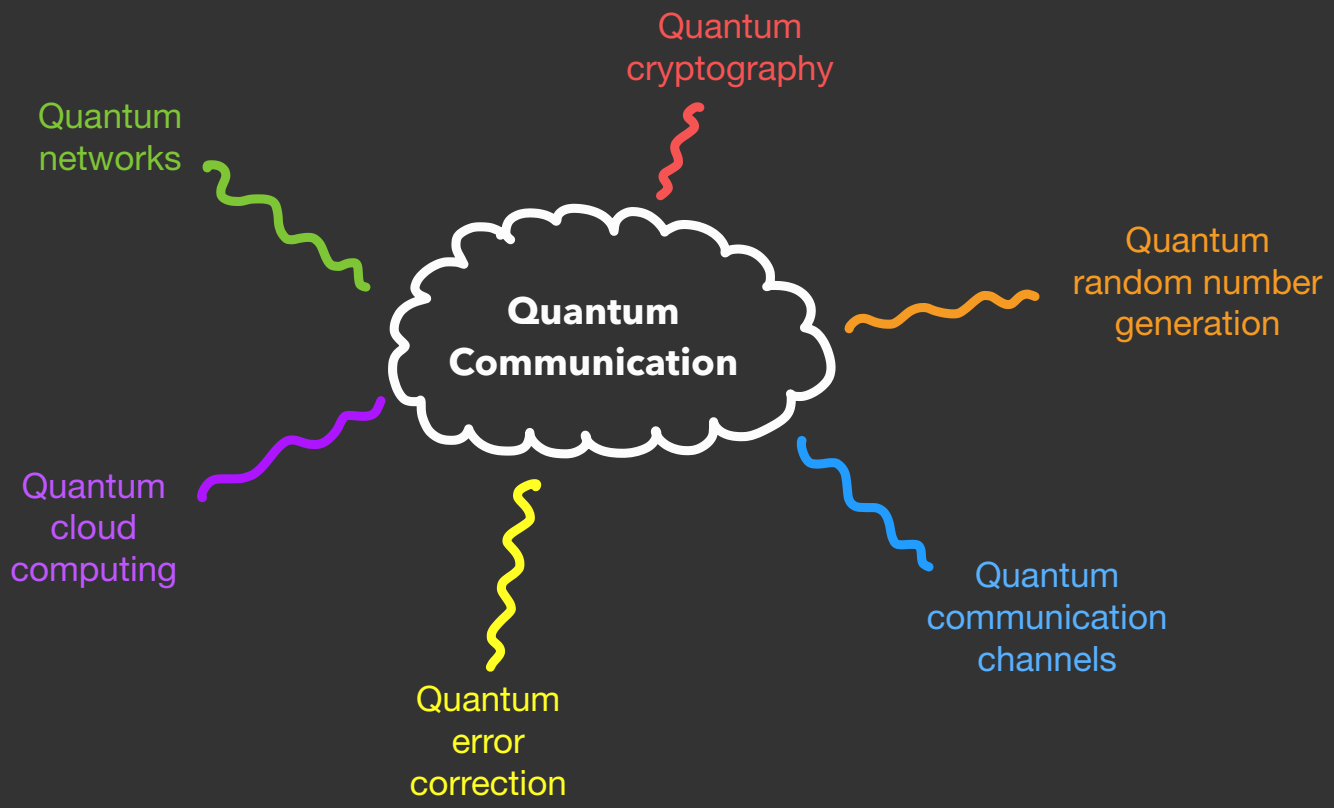

Quantum cryptography
Quantum networks
Quantum random number generation
Quantum Communication
Quantum cloud computing
Quantum communication channels
Quantum error correction

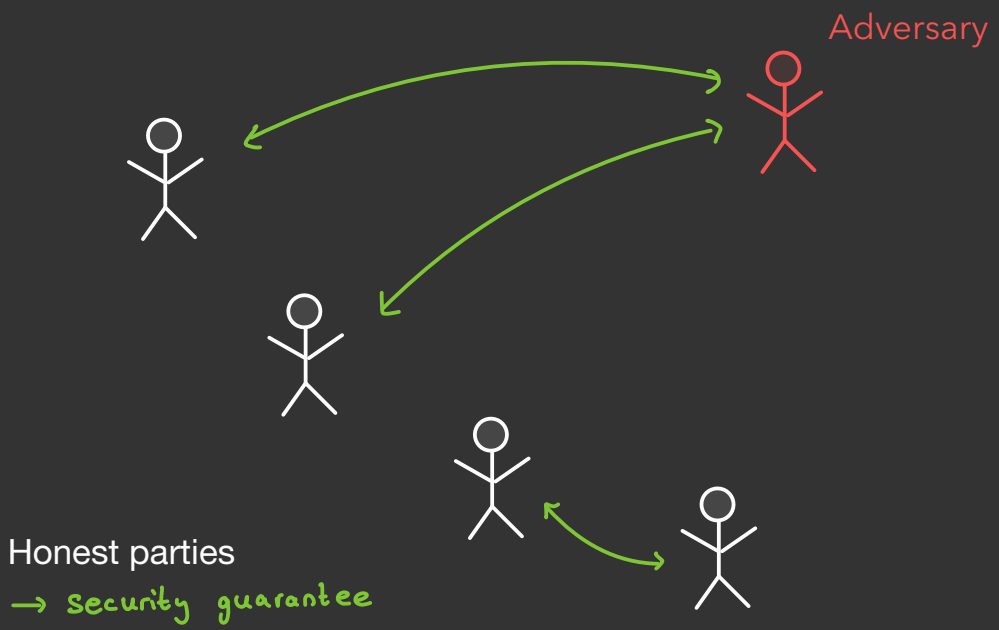
Two types of protocols:

1. Using quantum to enhance efficiency:
   - Super-dense coding ← transmitting two bits of information with one use of the channel
   - Quantum source coding ← efficient compression of quantum information
2. Using quantum to enhance security:
   - Quantum key distribution ← Unbreakable security from quantum principles
   - Quantum random number generation ← Provably unpredictable numbers
   - Cloud computing (e.g. blind quantum computing) ← secret computation on a quantum sever

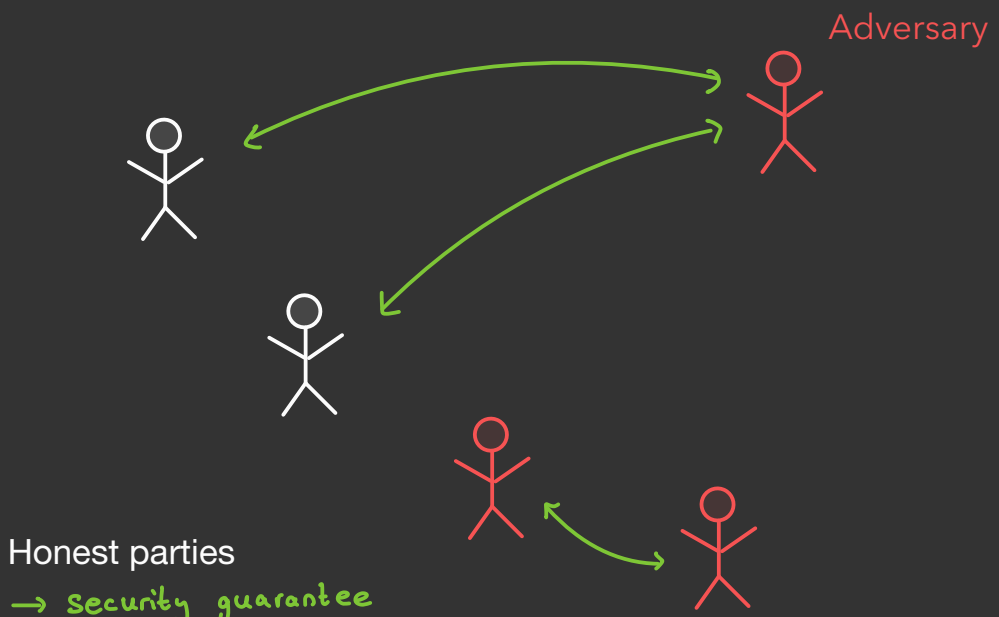
Security in quantum communication

What is security?

What is security?



What is security?

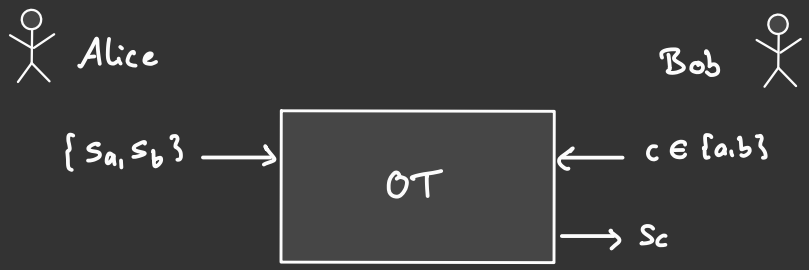


Security proof for a
communication protocol

Assumptions  Security guarantee

Oblivious transfer

universal for two-party cryptography



Security proof for a communication protocol

Assumptions → Security guarantee

Classically: computational assumptions

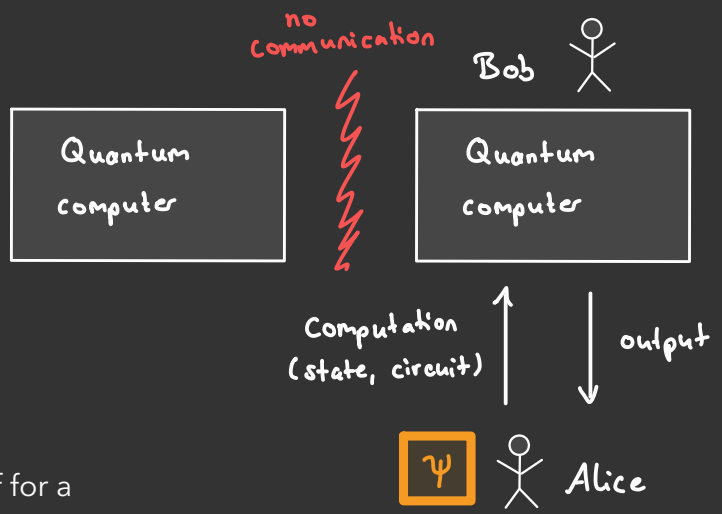
Quantum?

Also not without assumptions :-(

e.g., Bob only has bounded quantum memory

- Bob receives the correct bit
- Bob cannot learn the other bit
- Alice does not learn c

Blind quantum computing



Security proof for a communication protocol

Assumptions

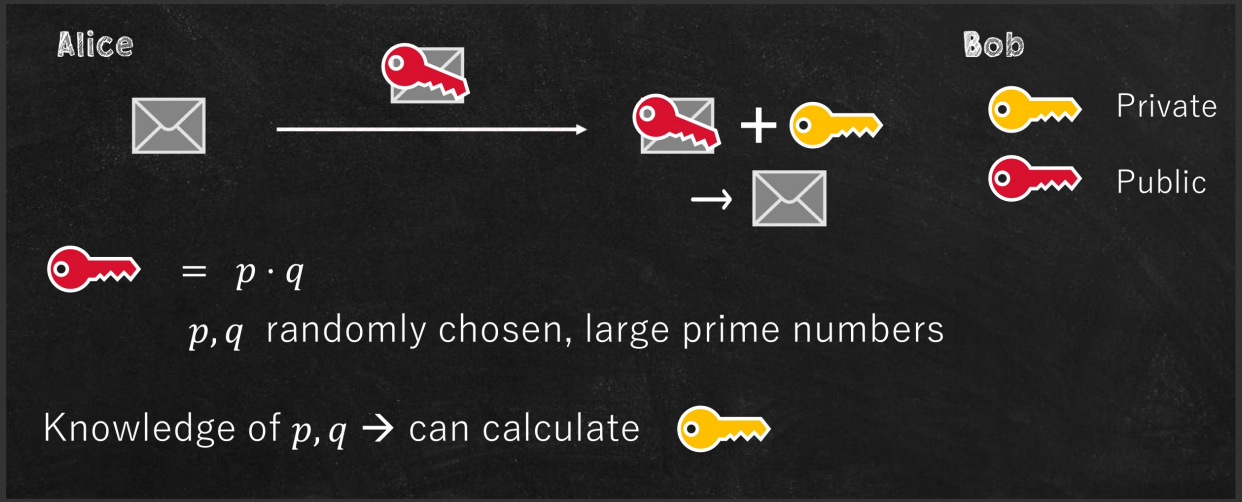
Classically: impossible
Quantum: Alice can prepare quantum states
Classical Alice: Need additional assumption, e.g. second quantum computer

Security guarantee

- The output is correct
- Bob learns nothing about the circuit, the input, and the output

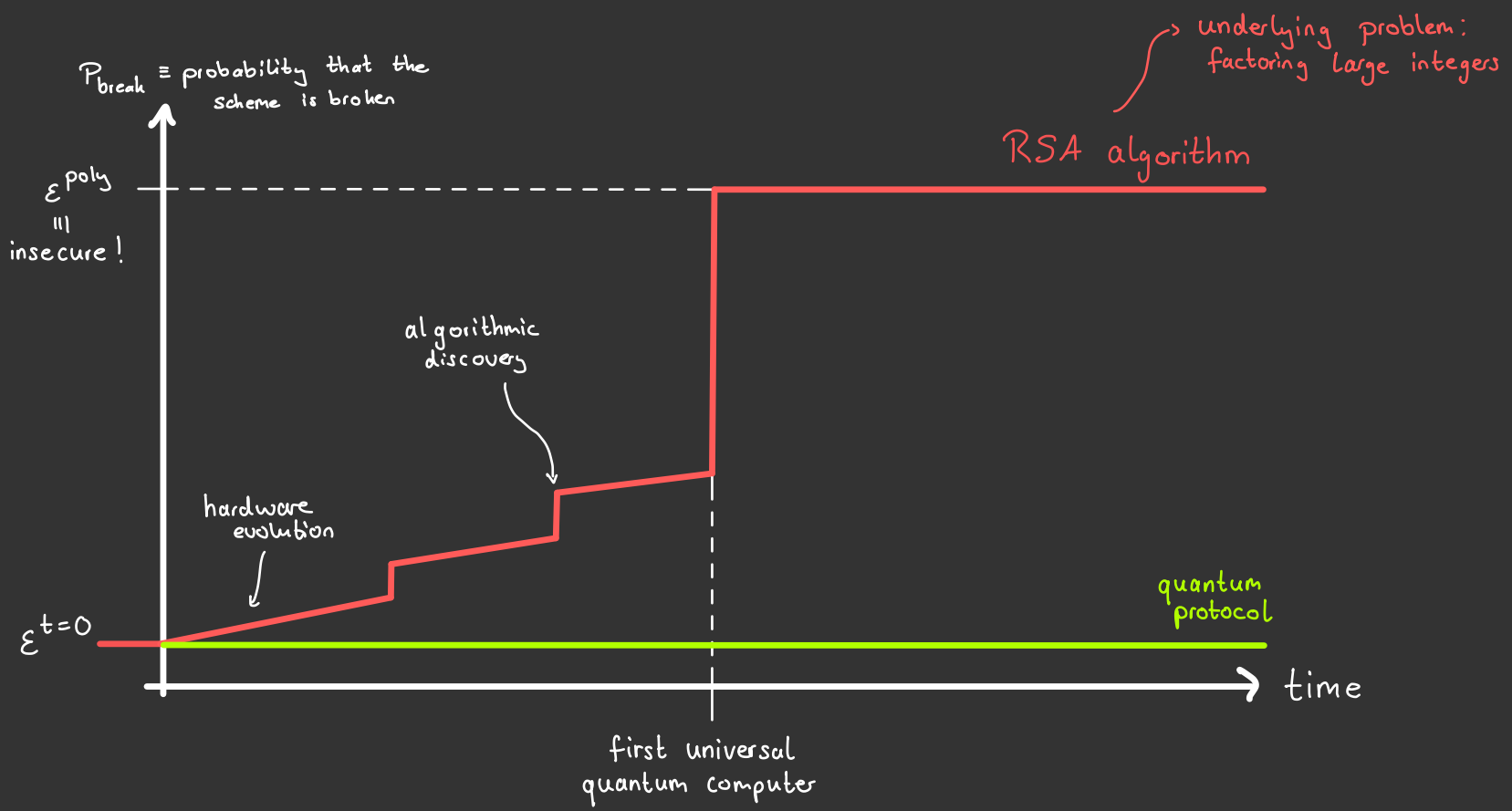
Secure message transmission

Classically: RSA



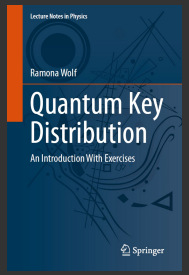
Assumption: Factoring large numbers is hard

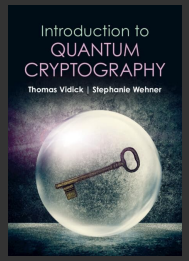
Not for a quantum computer!


P_{break} ≡ probability that the scheme is broken
underlying problem: factoring large integers
RSA algorithm
ε^{poly}
≡
insecure!
algorithmic discovery
hardware evolution
$\varepsilon^{t=0}$
quantum protocol
time
first universal quantum computer

References:

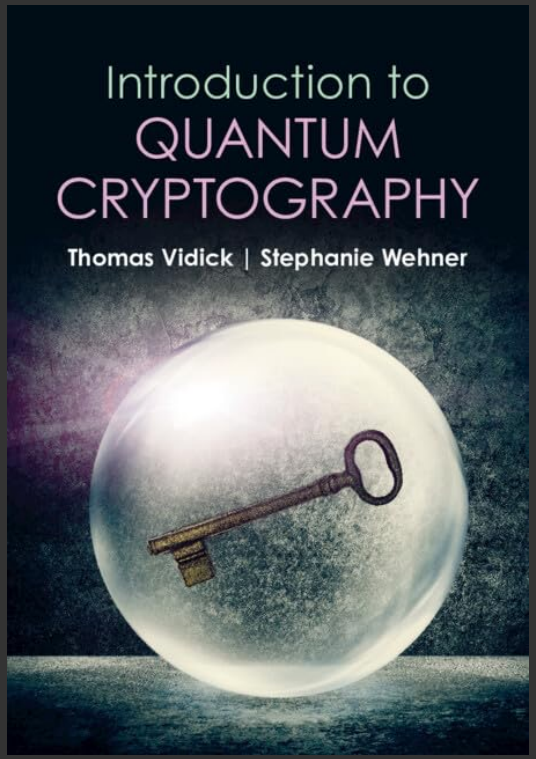
- Textbooks:
  - Thomas Vidick and Stephanie Wehner, "Introduction to quantum cryptography"
  - Ramona Wolf, "Quantum key distribution"





- Articles:
  - R. Renner and C. Portmann, "Security in quantum cryptography", Rev. Mod. Phys. 94, 025008 (2022), arXiv: 2102.00021
    Definition of security, composability
  - R Renner and R. Wolf, "Quantum advantage in cryptography", AIAA Journal 61 (5) (2023), arXiv: 2206.04078
    Non-technical introduction to QKD and current challenges
  - M. Tomamichel and A. Leverrier, "A largely self-contained and complete security proof of QKD", Quantum 1 (14) (2017), arXiv: 1506.08458
    Detailed security proof including all steps (technical paper)

More about quantum cryptography:



More about QKD: