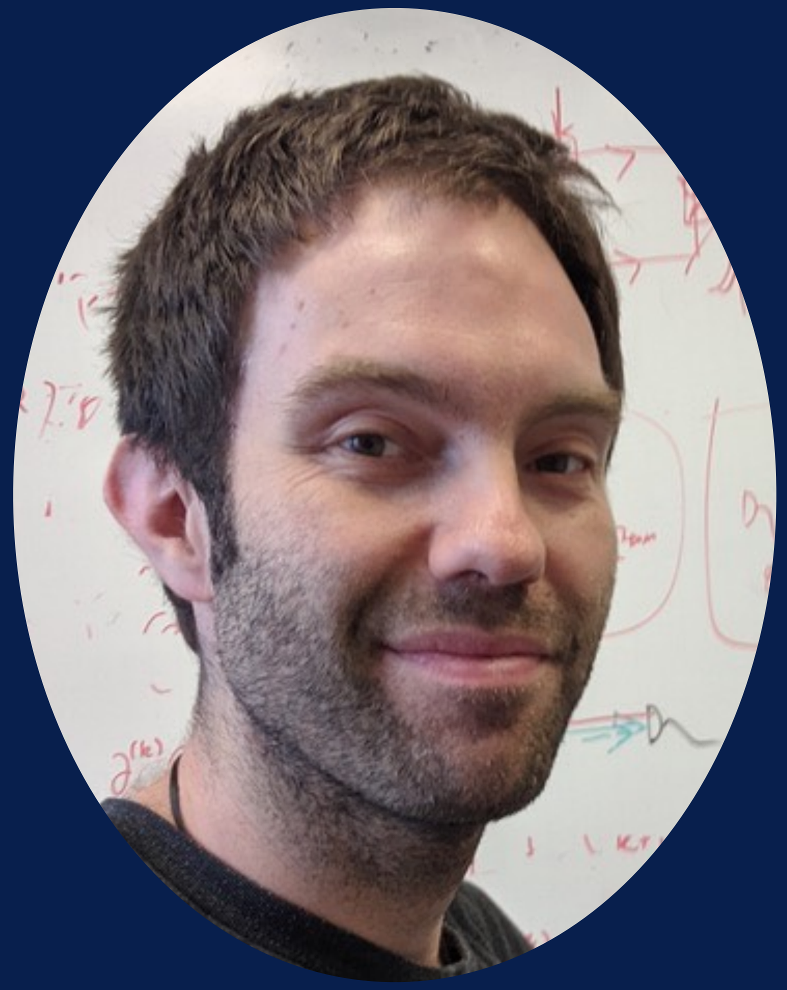
Building quantum networks at the local area scale

Qline: A quantum communication architecture by VeriQloud

Marc Kaplan, VeriQloud
QIRG Virtual Meeting, 02/02/2022

VeriQloud

About VeriQloud



Josh Nunn
University of Bath

Marc Kaplan
VeriQloud

Elham Kashefi
Sorbonne University
University of Edinburgh

- Located in Paris, France
- Quantum networks: architecture, software and application
- Current networks: QKD
- Future networks: toward a quantum internet
- Secure quantum cloud computing

Fundings and ecosystem

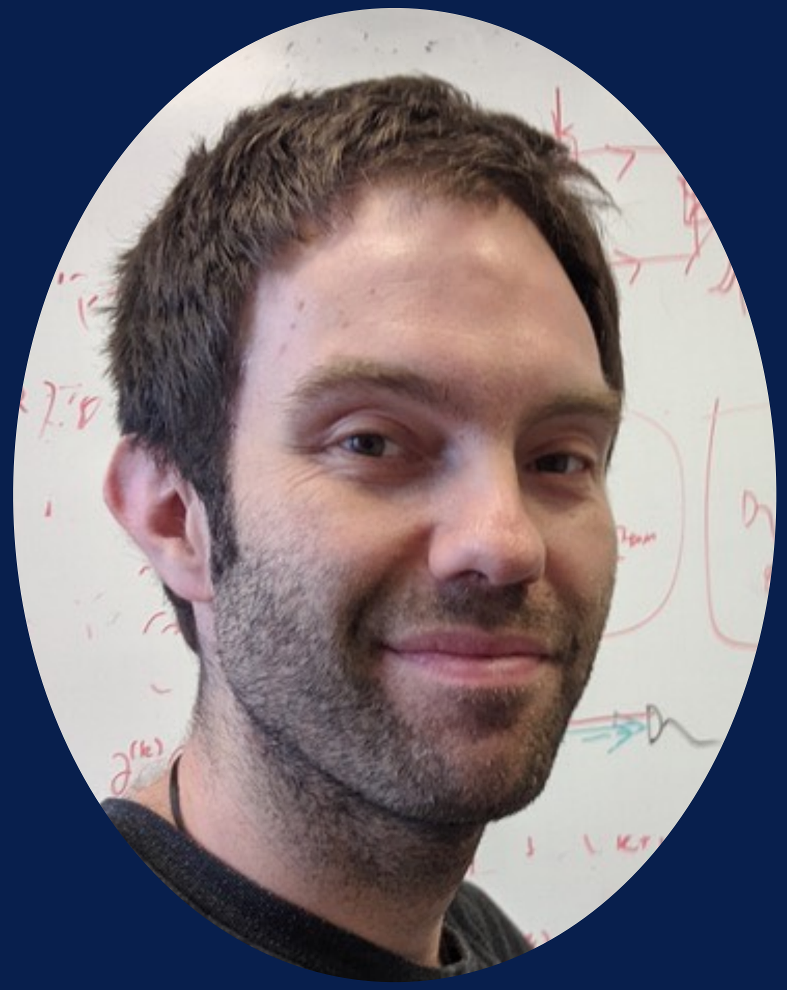
Support from french Institutions
DGA (French Darpa), BPI (Public investment bank)

Customers

Research projects

Networks

Qline: A quantum communication architecture



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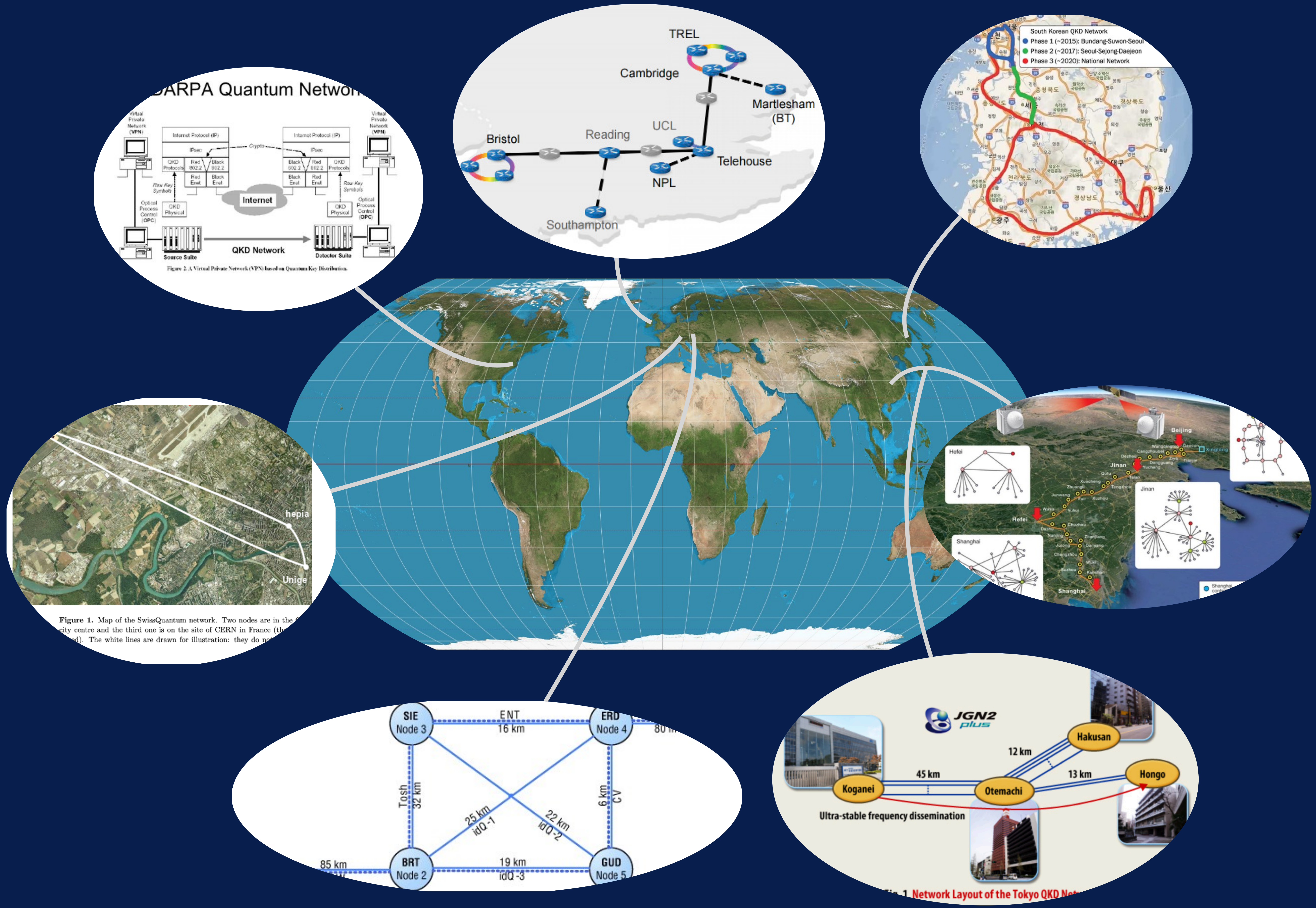
Quantum networks around the world



EuroQCI Project

US Quantum Internet

Advantages of quantum key distribution

VeriQloud

- ➡ Unconditional / Everlasting security implies Long-term security for classified, genomic, energy, healthcare, industry, finance…
- ➡ Key distribution for symmetric cryptography (AES)
- ➡ Prevents « store now, break later » attacks (Data Harvesting)
- ➡ Current encryption is vulnerable to future technical progresses and scientific breakthrough, QKD is not

With quantum key distribution (QKD), quantum networks provide **unconditional security.**

Main issue: scaling these networks with current technologies is expensive and injects vulnerabilities with trusted nodes

Qline: the quantum ethernet, by VeriQloud

- ➡ Fully-connected quantum communication infrastructure
- ➡ Trusted-node free
- ➡ Scalable with standard telecom components
- ➡ Can connect quantum computers in the future

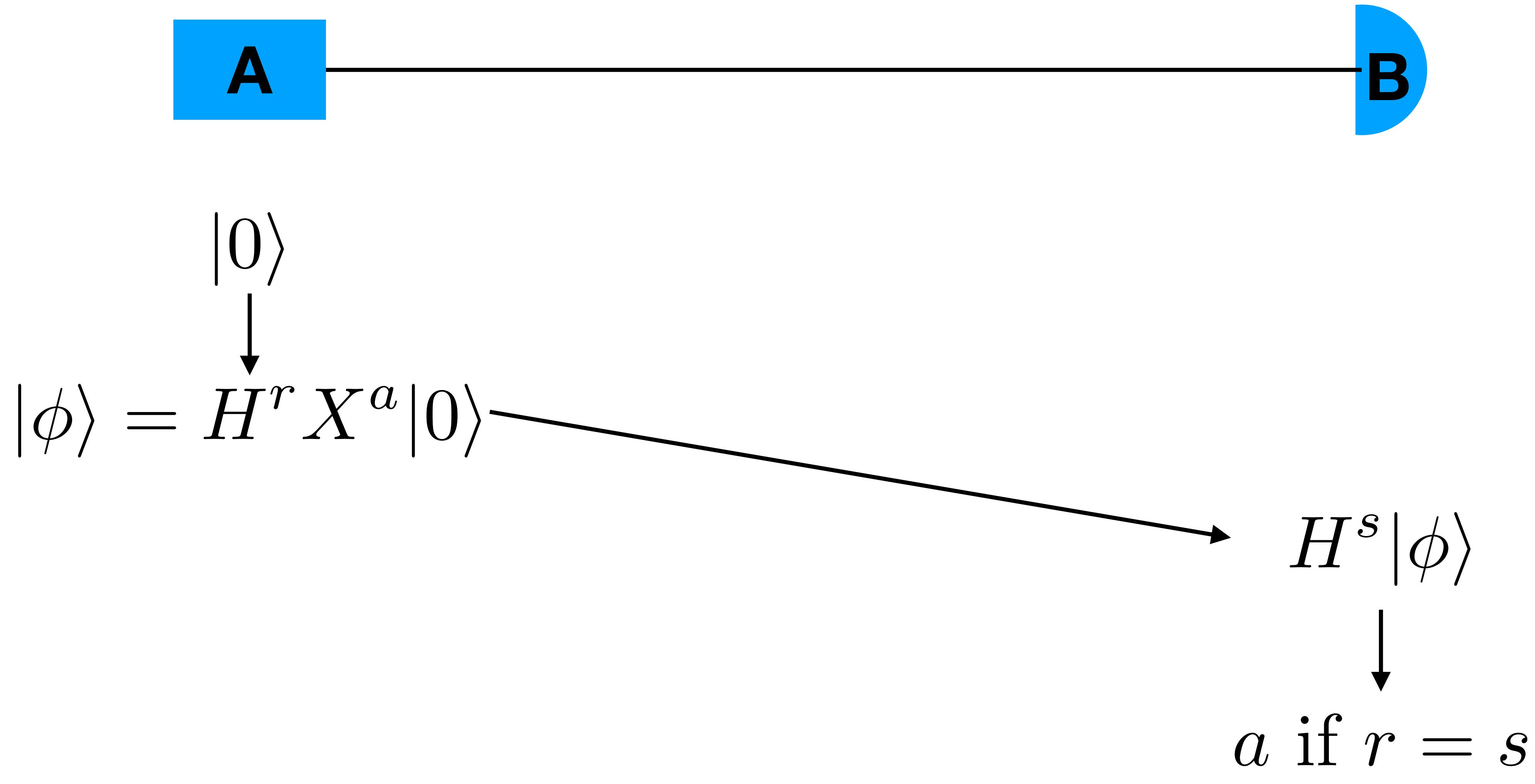
A full-stack solution for quantum cybersecurity at the **local-area scale**

Qline: the quantum ethernet, by VeriQloud

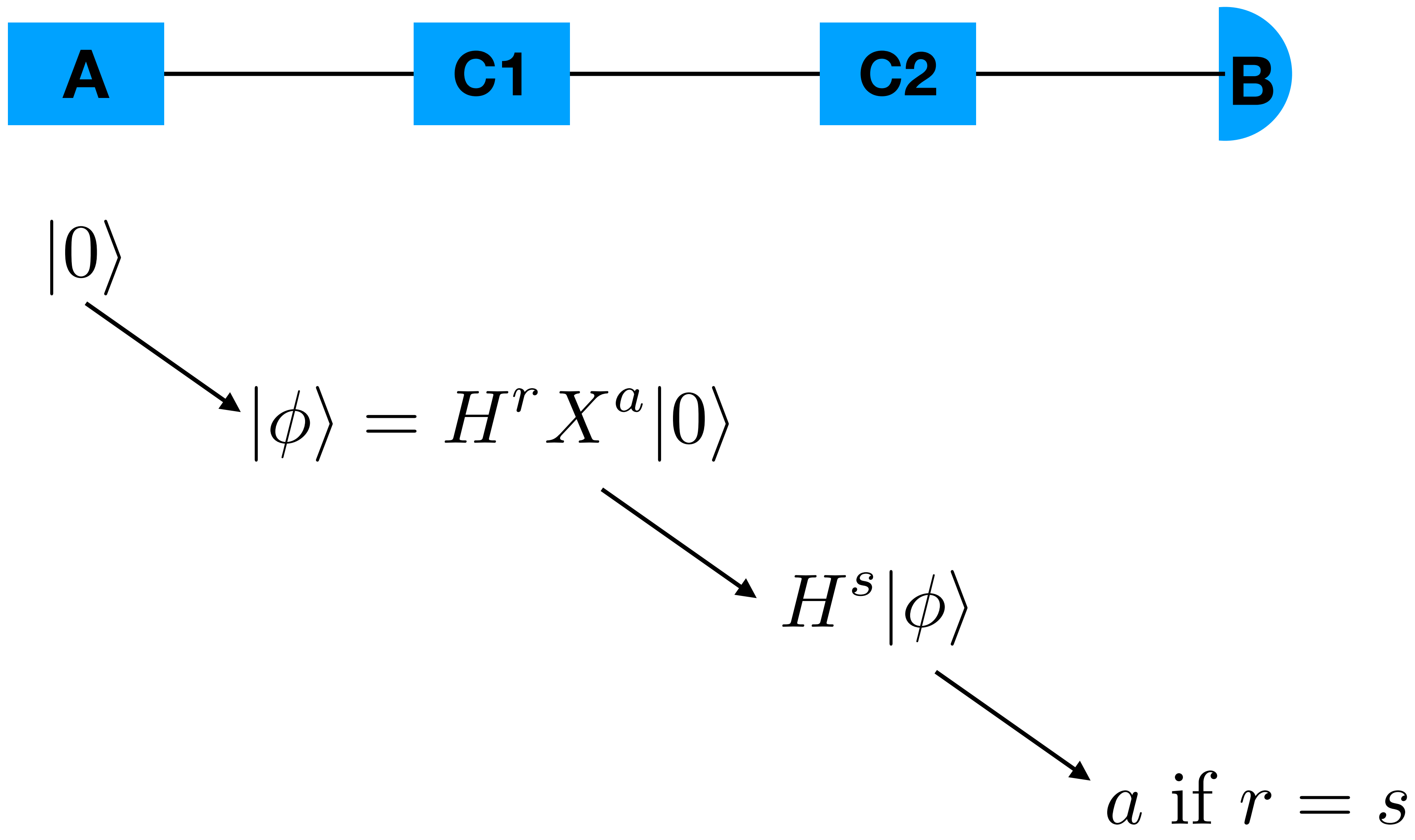
1. The Qline Protocol
2. Security of Qline in theory and practice
3. Today's use-cases
4. Future developments

The Qline Protocol

Standard QKD

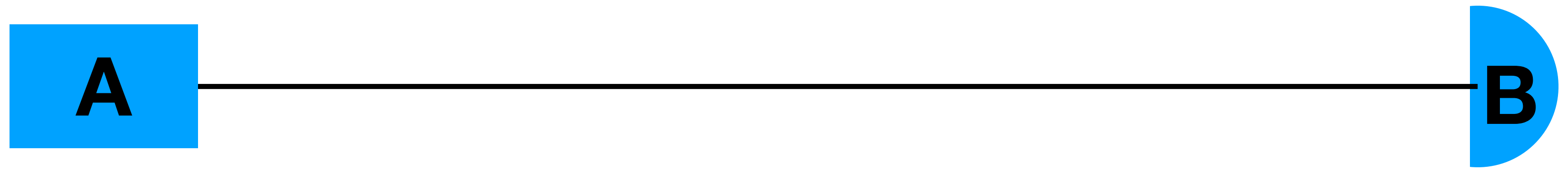


Qline



The Qline Protocol

Standard QKD



$$|0\rangle$$

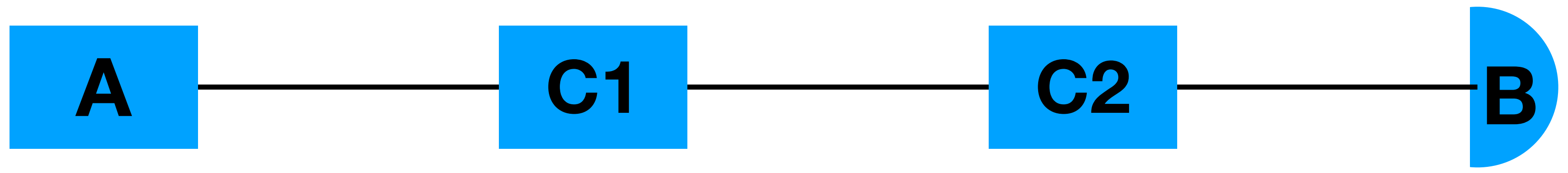
$$\downarrow$$

$$|\phi\rangle = H^r X^a |0\rangle \longrightarrow H^s|\phi\rangle$$

$$\downarrow$$

$$a \text{ if } r = s$$

Qline

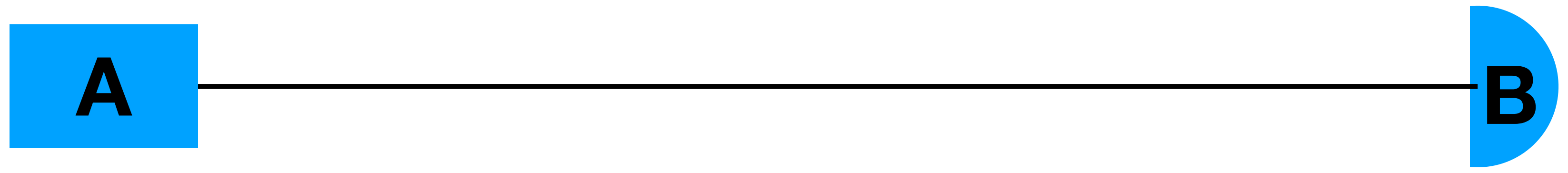


$$|0\rangle \longrightarrow |\phi\rangle = H^r X^a |0\rangle \longrightarrow X^b H^s|\phi\rangle \longrightarrow a \oplus b \text{ if } r = s$$

The Qline Protocol

Standard QKD

Qline

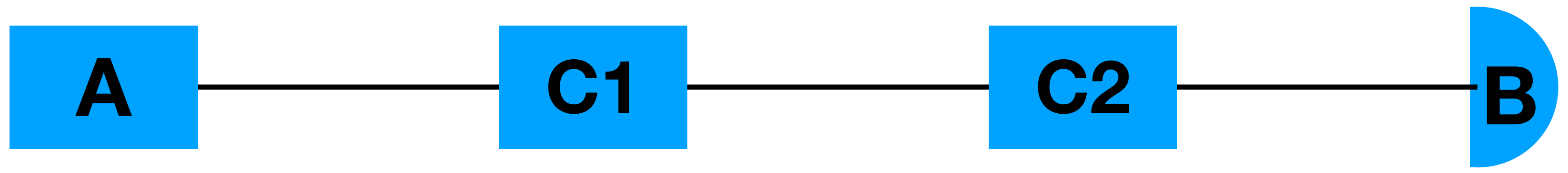


$$|0\rangle$$

$$|\phi\rangle = H^r X^a |0\rangle$$

$$H^s |\phi\rangle$$

$$a \text{ if } r = s$$



$$|0\rangle$$

$$|\phi\rangle = H^r X^a |0\rangle$$

$$X^b H^s |\phi\rangle$$

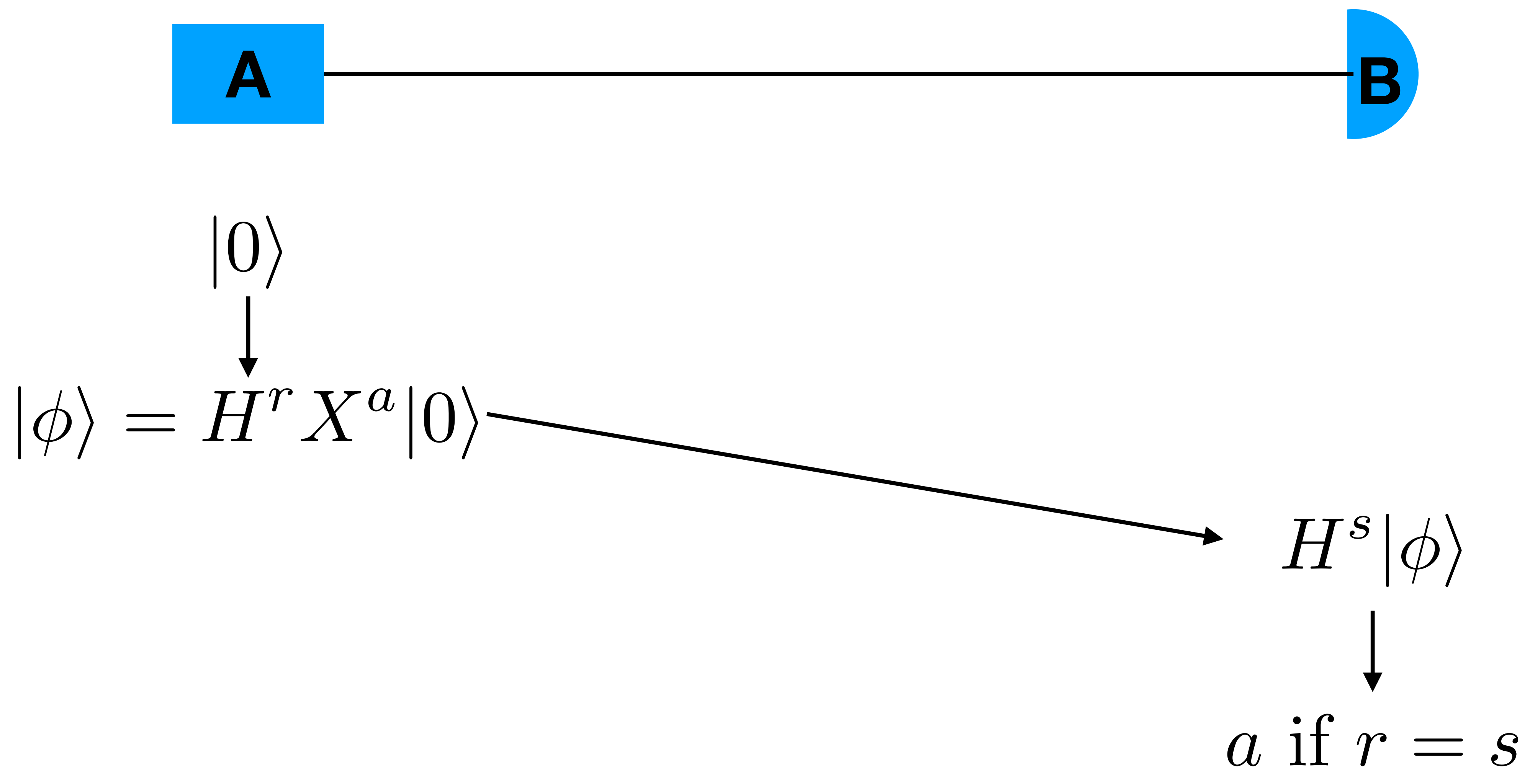
Randomness injection

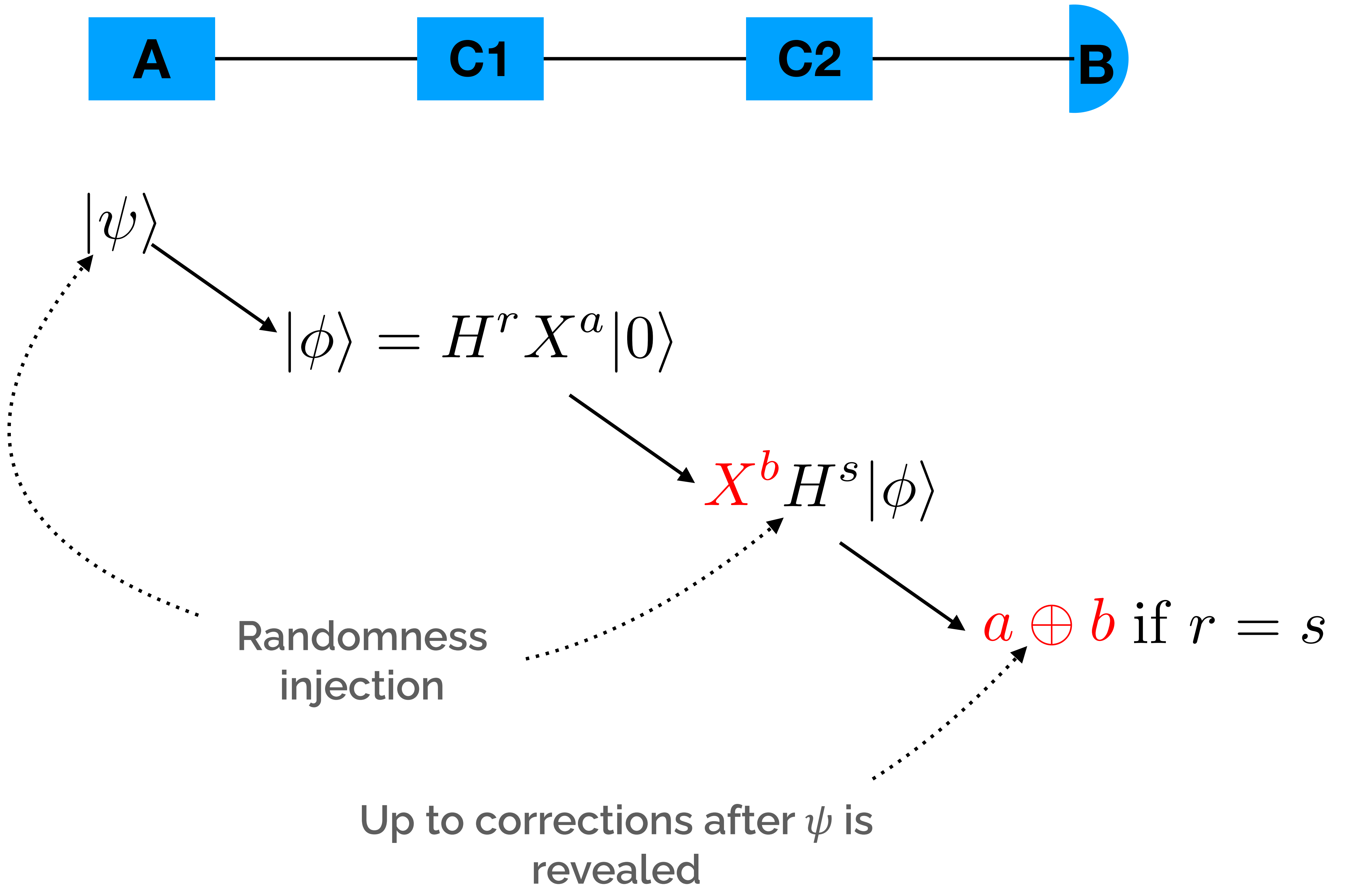
$$a \oplus b \text{ if } r = s$$

The Qline Protocol

Standard QKD

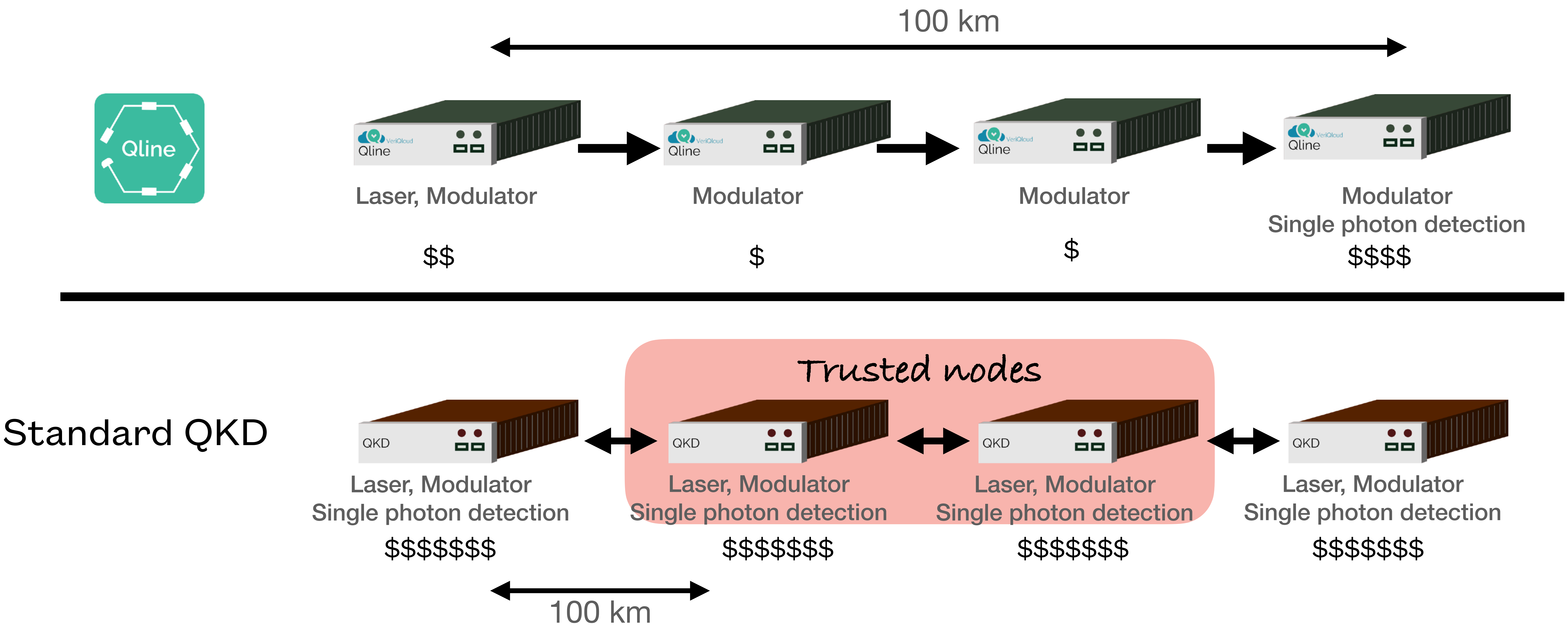
Qline





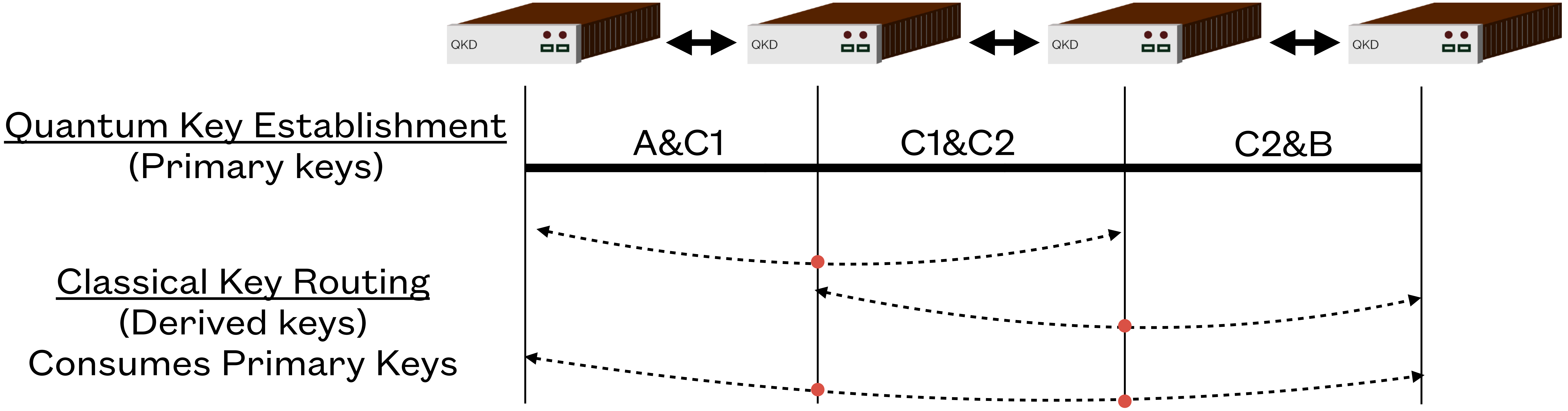
The Qline Protocol

Qline vs QKD



Qline vs QKD performances

Key establishment with QKD

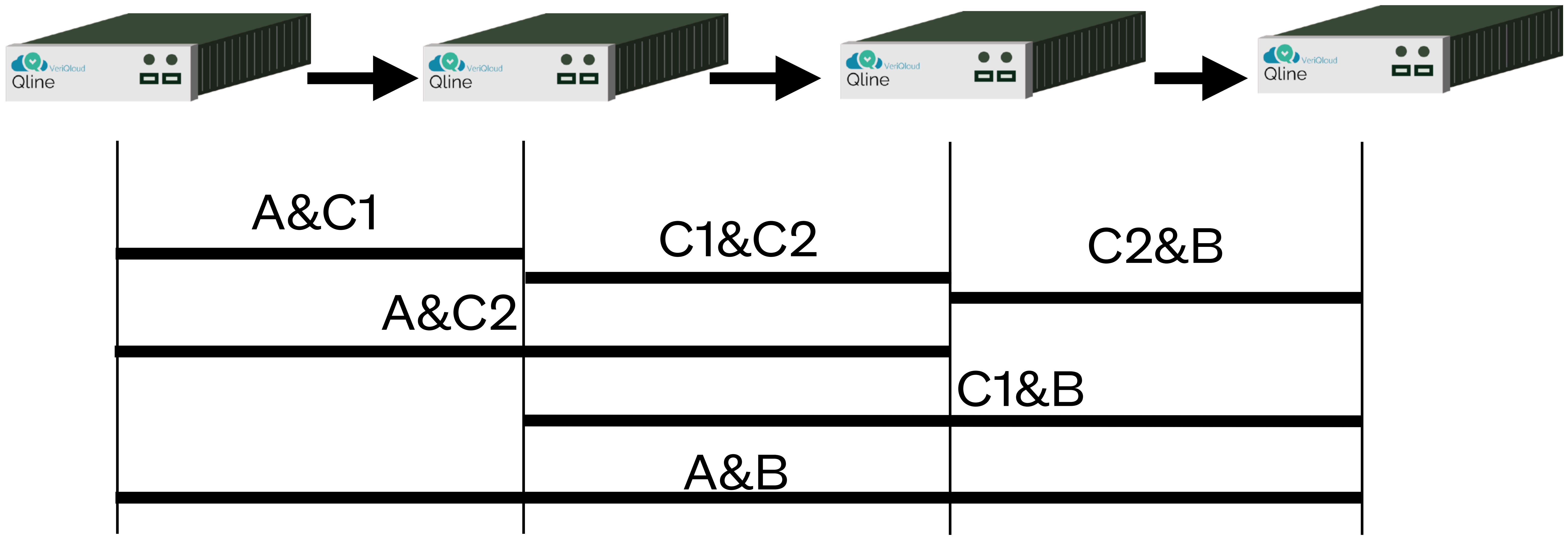


Qline vs QKD performances

Key establishment with Qline

No key routing

No Trusted nodes



Under the following assumptions

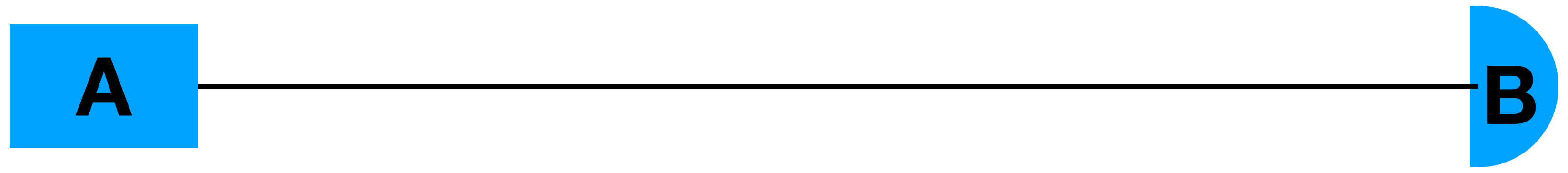
➡ Keys are uniformly distributed among pairs of nodes

➡ The cost is dominated by the one of detectors

The price-per-bit of keys is the same with QKD and Qline

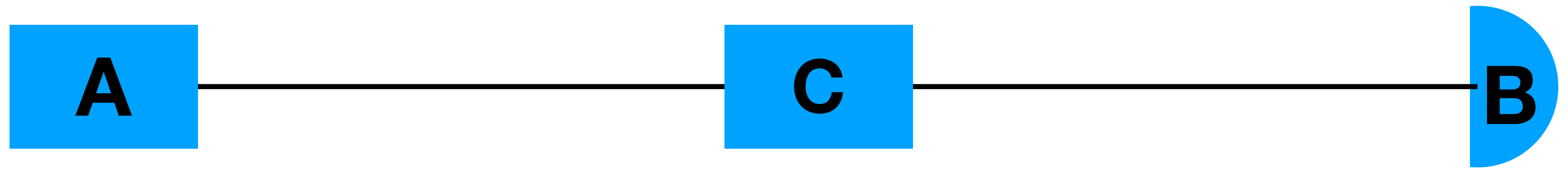
The security of Qline (Theory)

Standard QKD



Composable security from
A largely self-contained and complete security proof for quantum key distribution
Marco Tomamichel and Anthony Leverrier
Quantum 1, 14 (2017).

Qline



Our goal
Show that an attack on Qline implies an attack on standard QKD

The security of Qline (Theory)

Standard QKD

Qline

An eavesdropper « sees » the same state at all those points.

Extracting information in Qline is the same as extracting information in QKD

Side-channel attacks on Qline

QKD Side-channels → Same as QKD

Trojan Horse → Power-monitoring

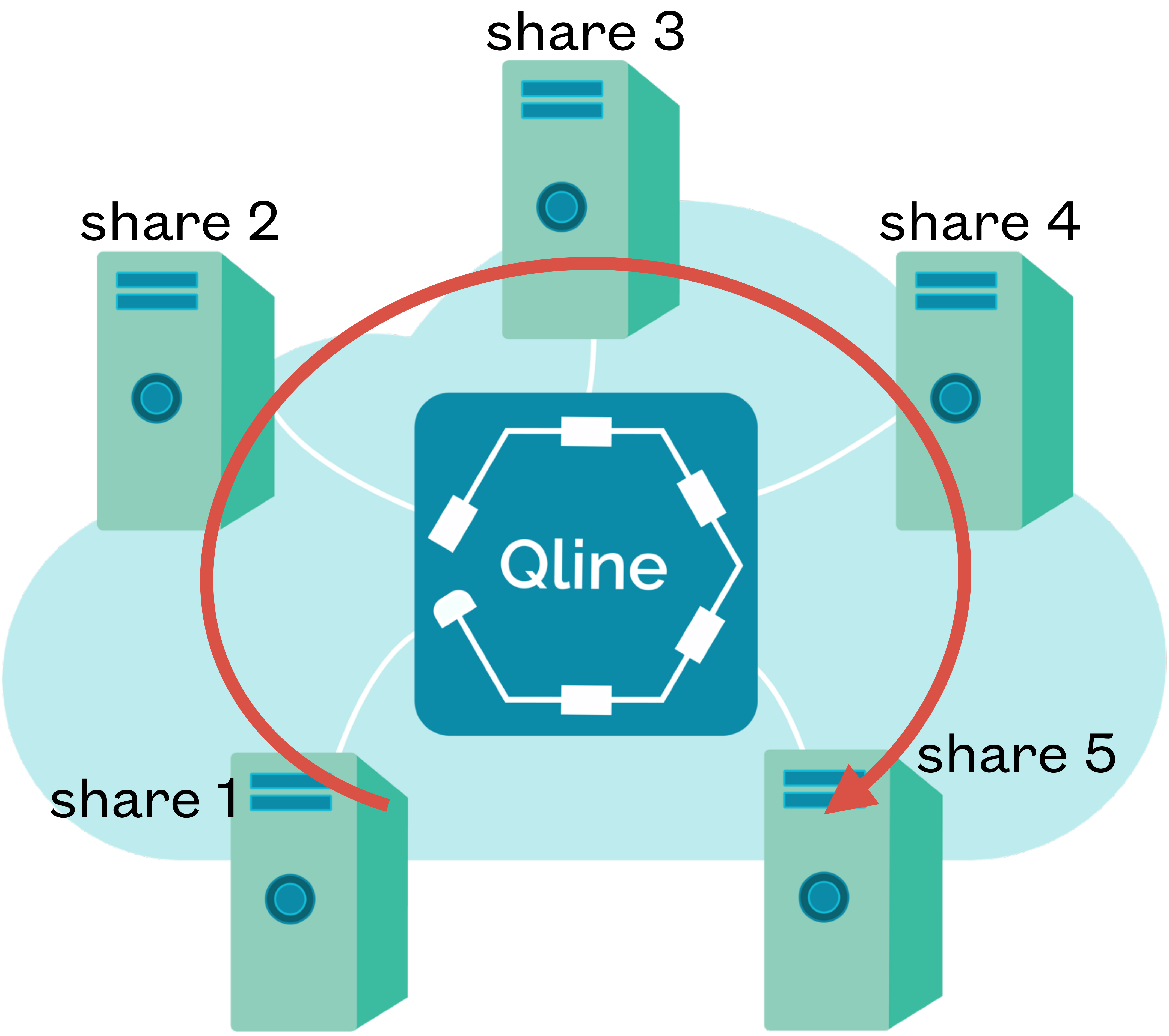
Photon counting → Work in progress

Application: last-kilometer of quantum networks

Qline as the base of metropolitan infrastructures

OpenQKD with Deutsche Telekom

Application: secure storage



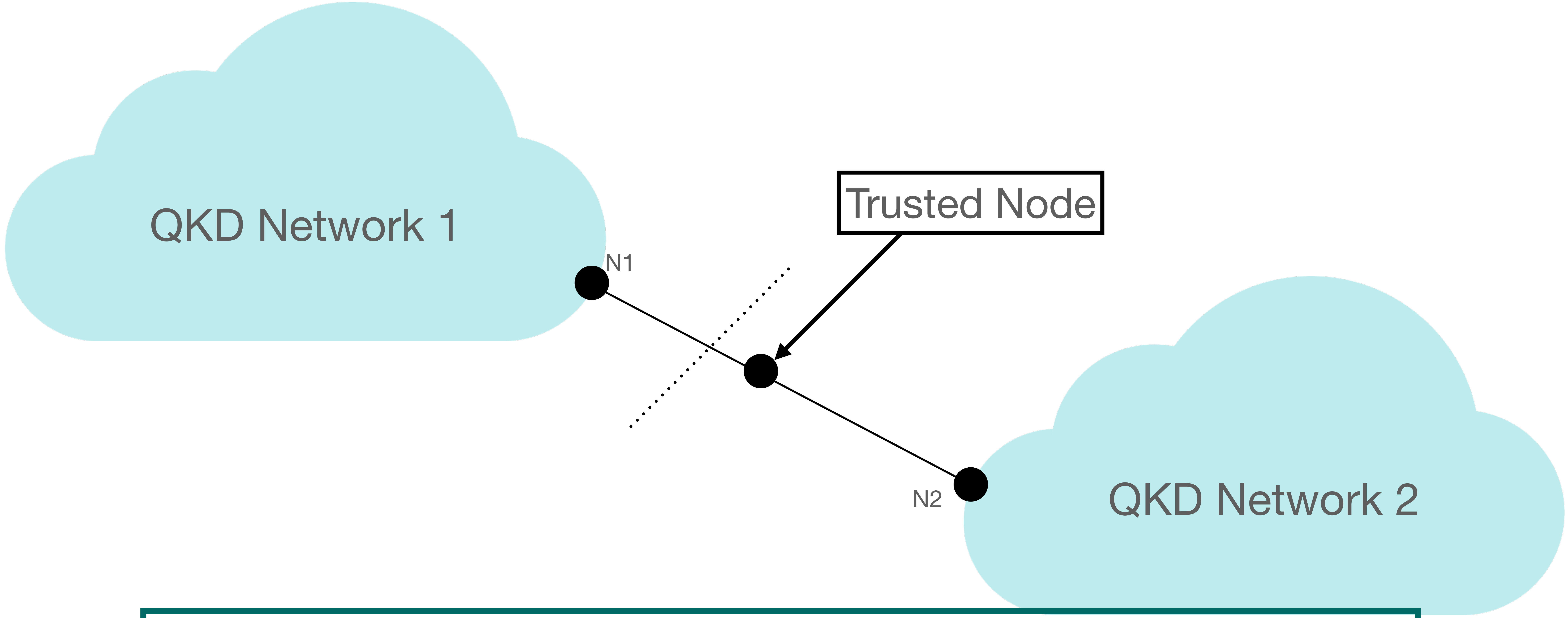
LINCOS - A Storage System Providing Long-Term Integrity, Authenticity, and Confidentiality

Johannes Braun, Johannes Buchmann, Denise Demirel, Matthias Geihs (TU Darmstadt, Germany) Mikio Fujiwara, Shiho Moriai, Masahide Sasaki, Atsushi Waseda (NICT, Japan)

ASIACCS 2017

- ➡ Quantum communication protects against data interception
- ➡ Classical cryptography protects against data leakage
- ➡ Continuous re-encryption and share redistribution
- ➡ Computation on shares
- ➡ **Qline**: No trusted nodes = less vulnerabilities

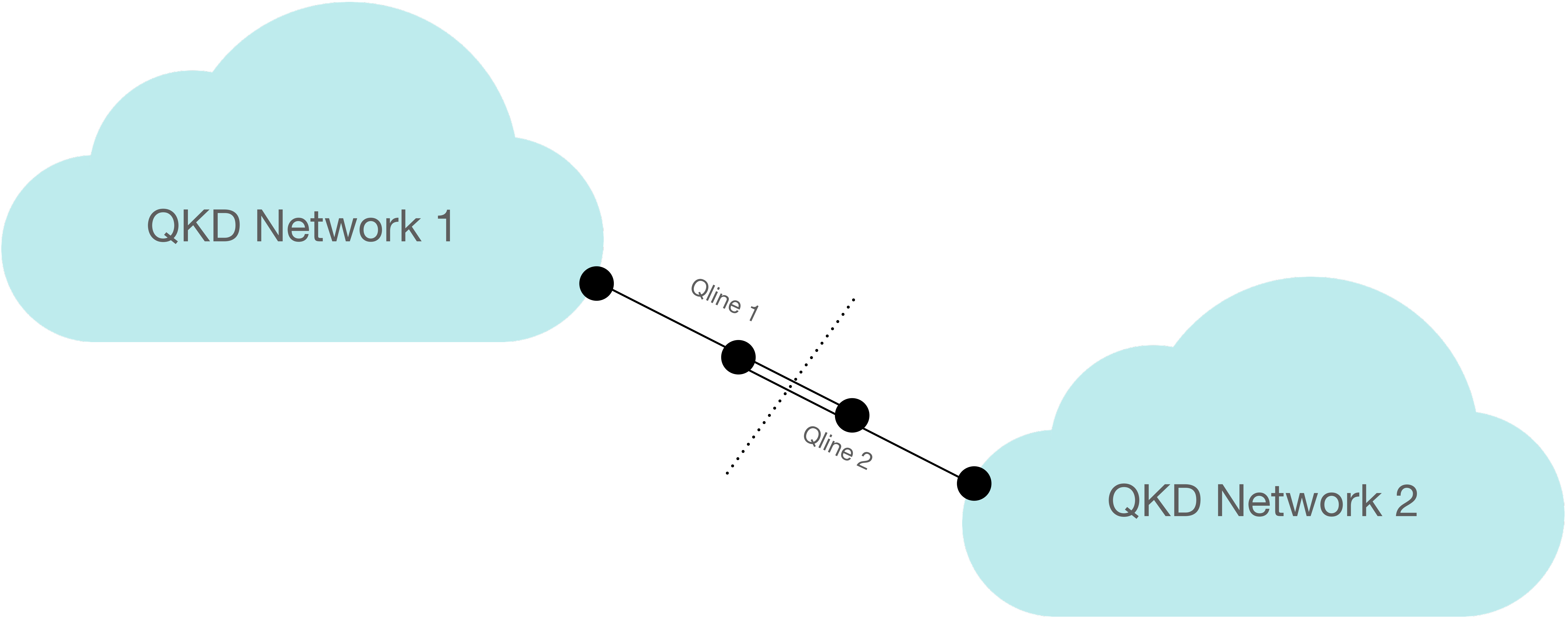
Application: QKD Network interconnection



Goal: Establish a shared key between N1 and N2

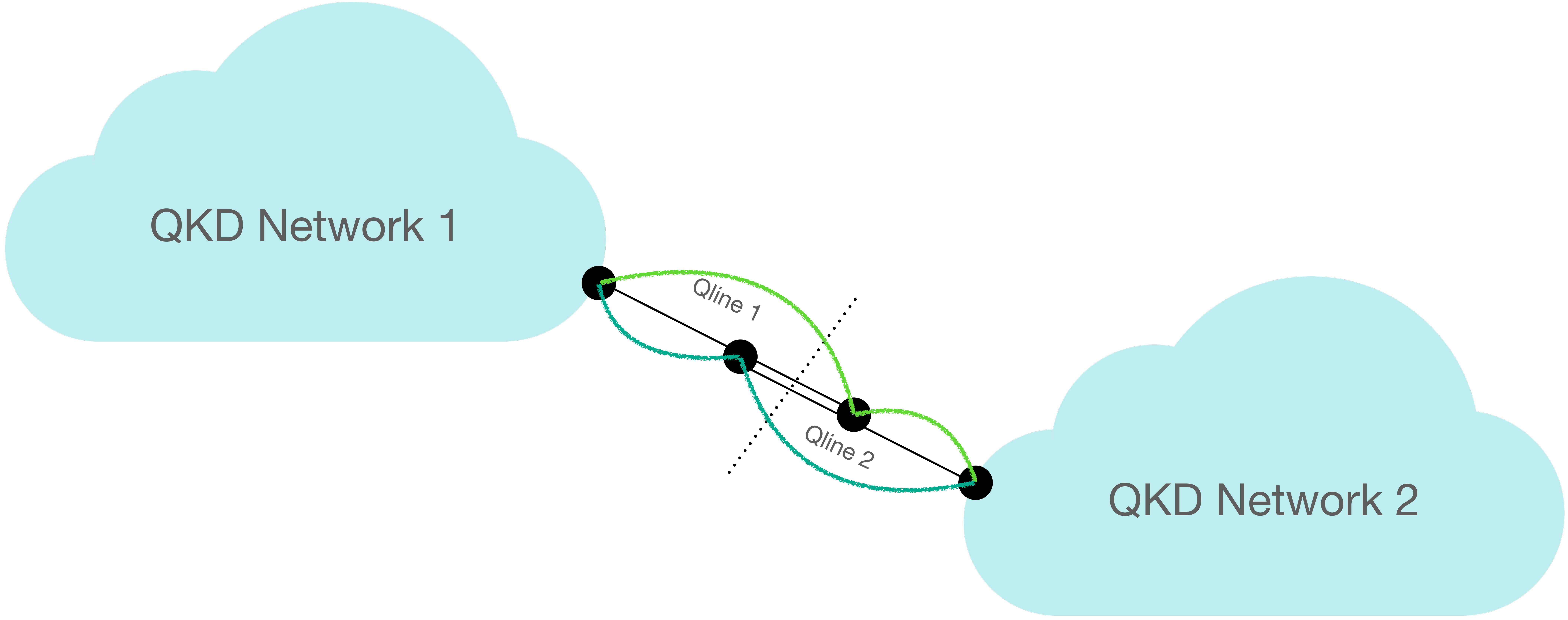
Problem: Who operates the trusted node?

Application: QKD Network interconnection with Qline



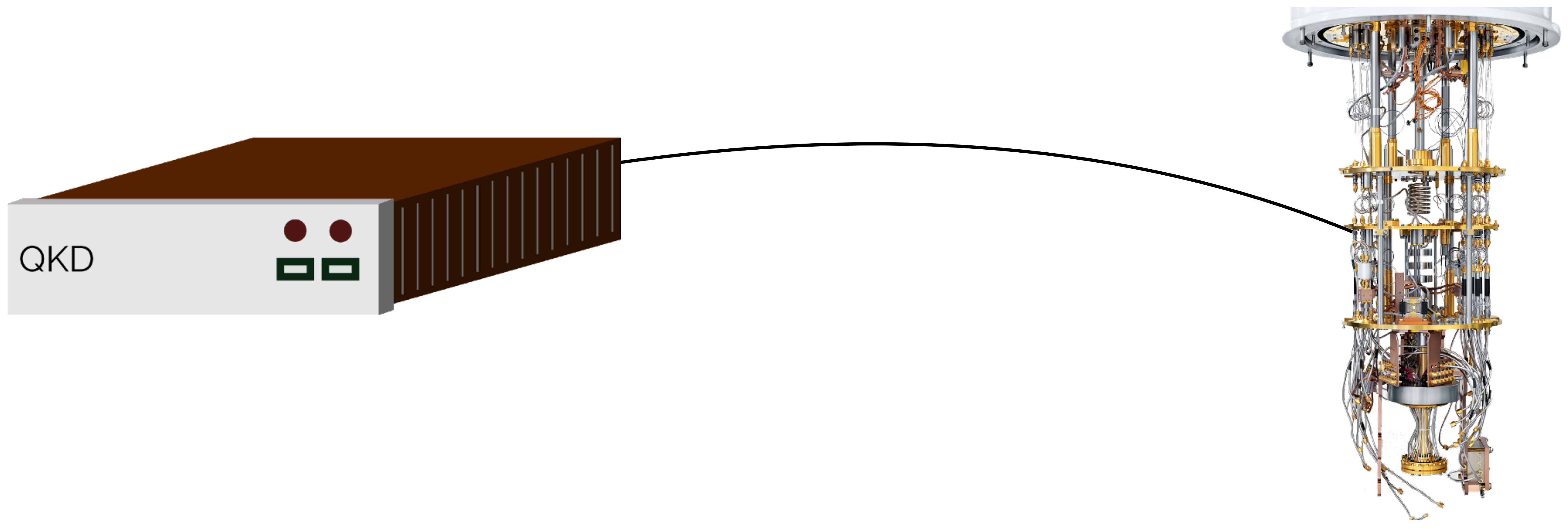
Two Qlines can route two independent keys from N1 to N2. None on the intermediate nodes is a trusted node

Application: QKD Network interconnection with Qline



Two Qlines can route two independent keys from N1 to N2. None on the intermediate nodes is a trusted node

Interlude: Verifiable blind quantum computing

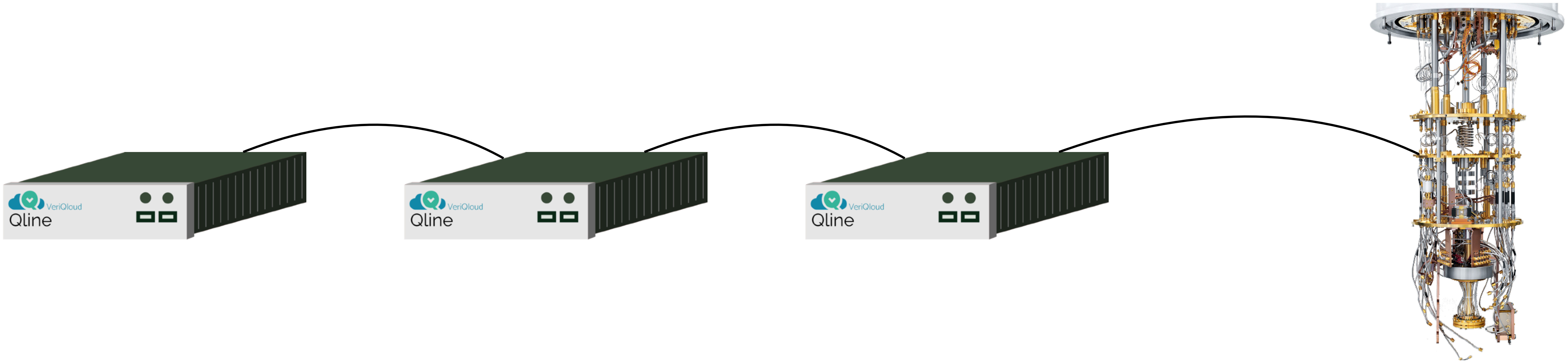


The light client delegates a quantum computation to a distant server with the following guarantees:

➡ **Blindness**: the server does not learn anything.

➡ **Verifiability**: any deviation from the original computation will be detected.

Application: Secure quantum cloud computing



- A scalable architecture for secure quantum cloud computing
- Applications to secure distributed quantum computing

Conclusion Qline: the quantum ethernet

VeriQloud

- ➡ Fully-connected quantum communication infrastructure with performance similar to QKD
- ➡ Secure and scalable
- ➡ Composable security, security against side-channel attacks
- ➡ Application to quantum networks, and secure storage
- ➡ A scalable and secure architecture for secure quantum cloud computing

Toward a quantum internet

VeriQloud

Making quantum cybersecurity feasible