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ALLIANCE

Use cases for the quantum Internet

Peter Hinrich

Belgrade, 28th October 2022



This project (QIA) has received funding from the European Union's Horizon Europe programme

SURF



**ICT infrastructure
& services**



**Digital innovation &
transformation**



**Knowledge sharing:
Expertise, training &
support**



**Acceleration of
members by
collaboration**

**SURF is the collaborative organisation for IT
in Dutch education and research**

SURF

IT facilities by SURF



HIGH-END COMPUTE SERVICES:

High-end computing solutions, in different flavors.



CUSTOM SERVICES & ANALYSIS:

Process, analyse, or visualise complex research data or big data.



DATA STORAGE & MANAGEMENT:

Easily accessible storage on disk or tape, data management advise.



TRUST & IDENTITY

Secure & trusted access to many services with federated identity management.

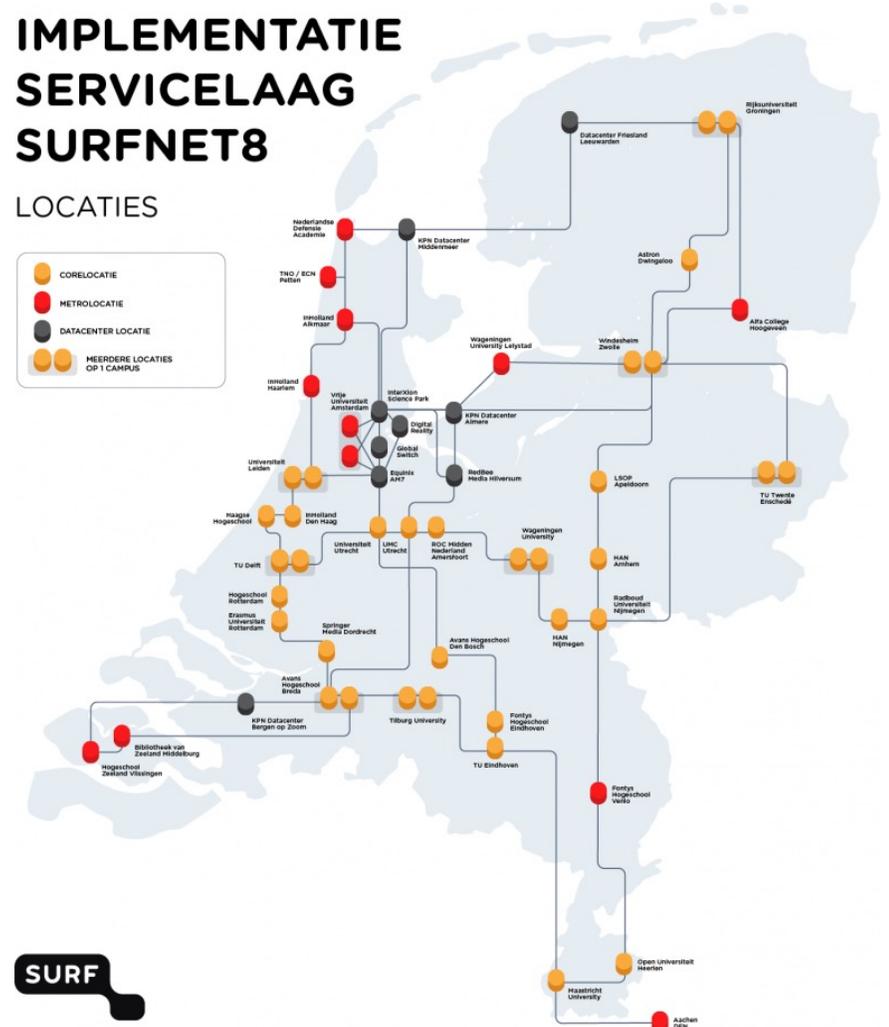
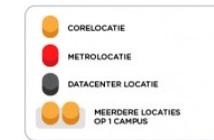


CONNECTIVITY:

Fast end-to-end connections tailored to your data sharing research needs.

IMPLEMENTATIE SERVICELAAG SURFNET8

LOCATIES

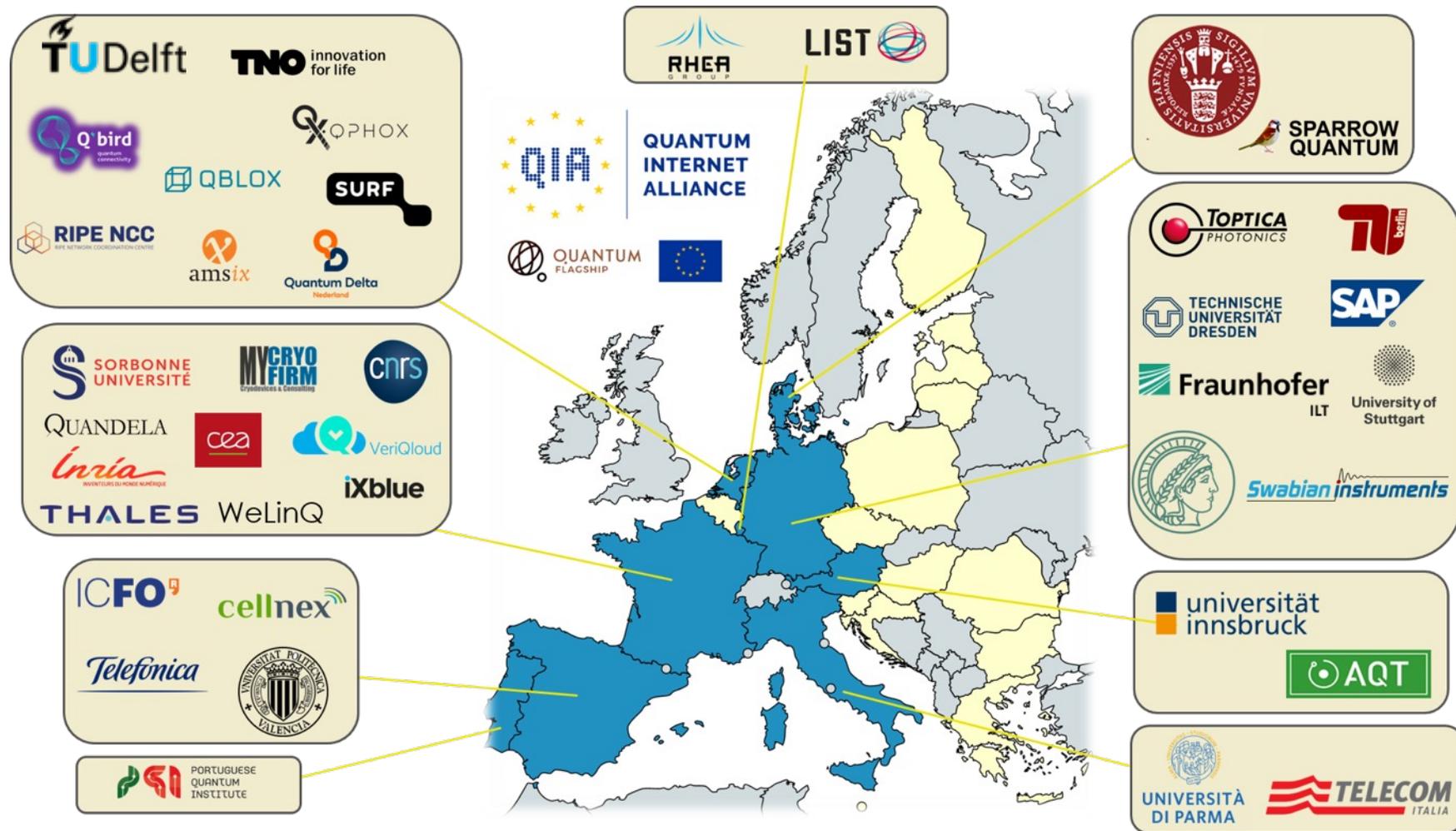


VERSIE: OKTOBER 2019



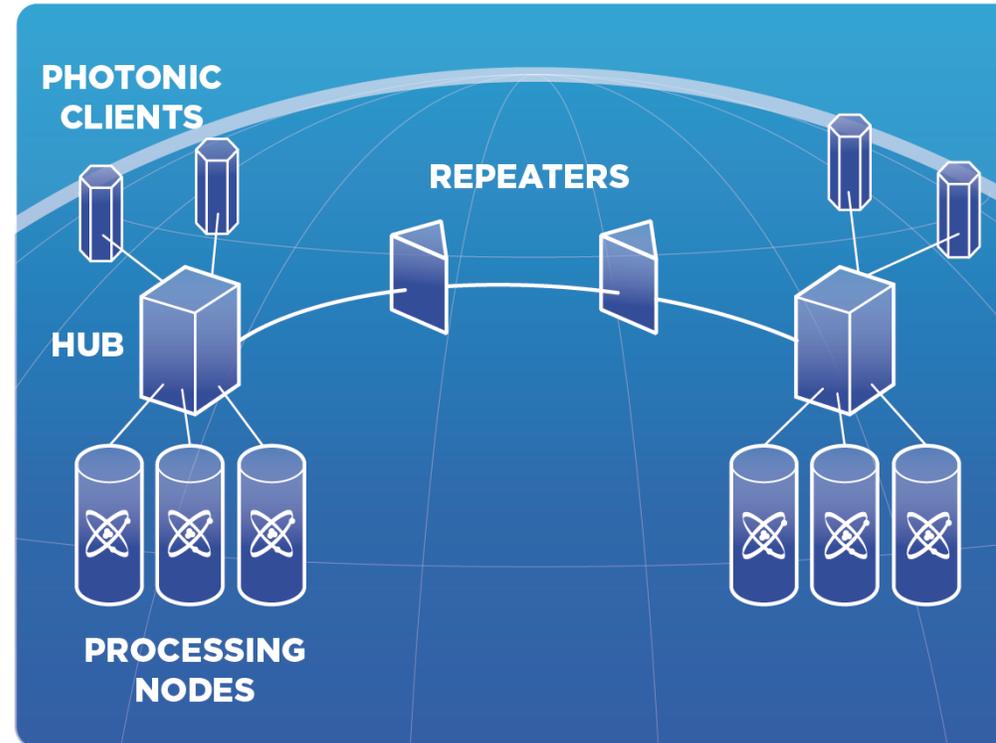
Quantum Internet Alliance (QIA)

40 Partners in 8 countries



QIA Objectives

Fully programmable quantum network prototype connecting two metropolitan scale networks by a long-distance fiber backbone using quantum repeaters



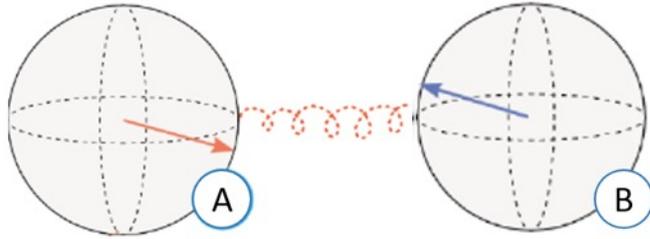
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What is Quantum Internet

Entanglement

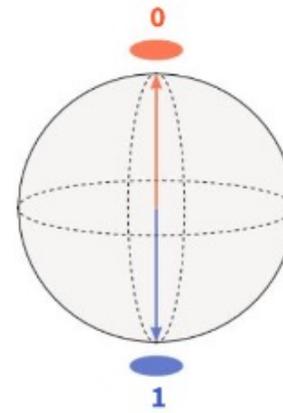


When two qubits are **entangled**, the outcome on the measurements on each of the qubits A and B will always be correlated even if they are separated by a long distance.

Quantum entanglement is used in quantum networks to teleport quantum information across the network

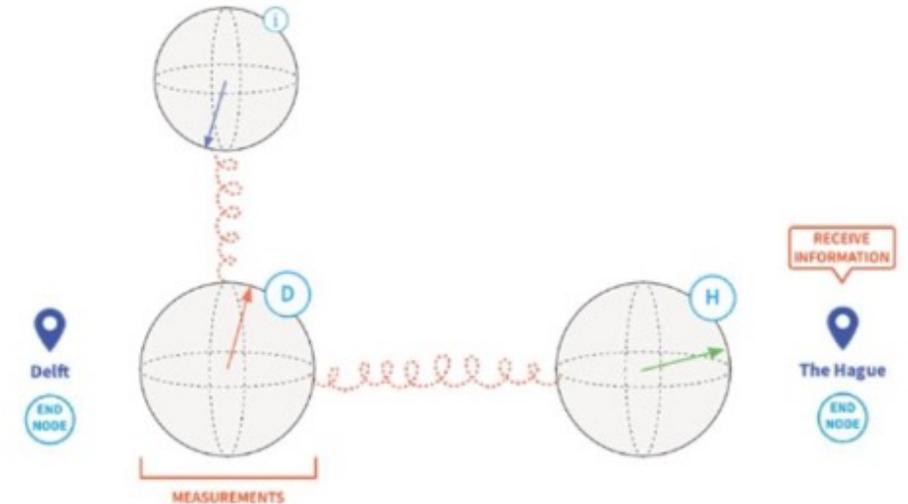
Quantum teleportation is a method to send qubits across a quantum network by making use of entanglement. Note that quantum teleportation does not allow for faster communication than light

QuBit



A quantum bit or **Qubit** is the quantum mechanical analog of a classical bit. Qubits are two-state quantum systems (0 and 1) that can be in a **Superposition** of both states 0 and 1. In quantum networks information is encoded and transmitted in/between qubits

Quantum teleportation



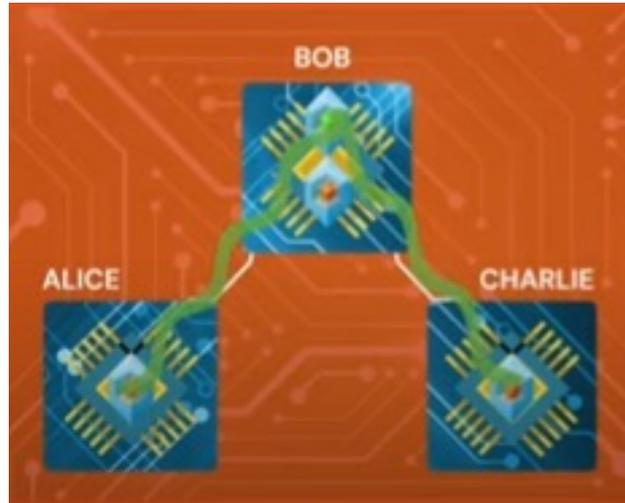
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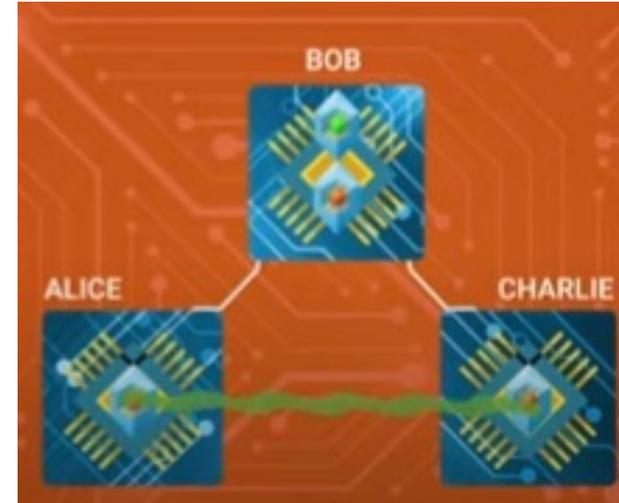
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What is Quantum Internet

Entanglement swapping



To enable quantum communication between independent remote nodes (Alice & Charlie) not directly linked, we first create entanglement across a third node.



Then we teleport the entanglement to the outer two-nodes. This is called **entanglement swapping**.



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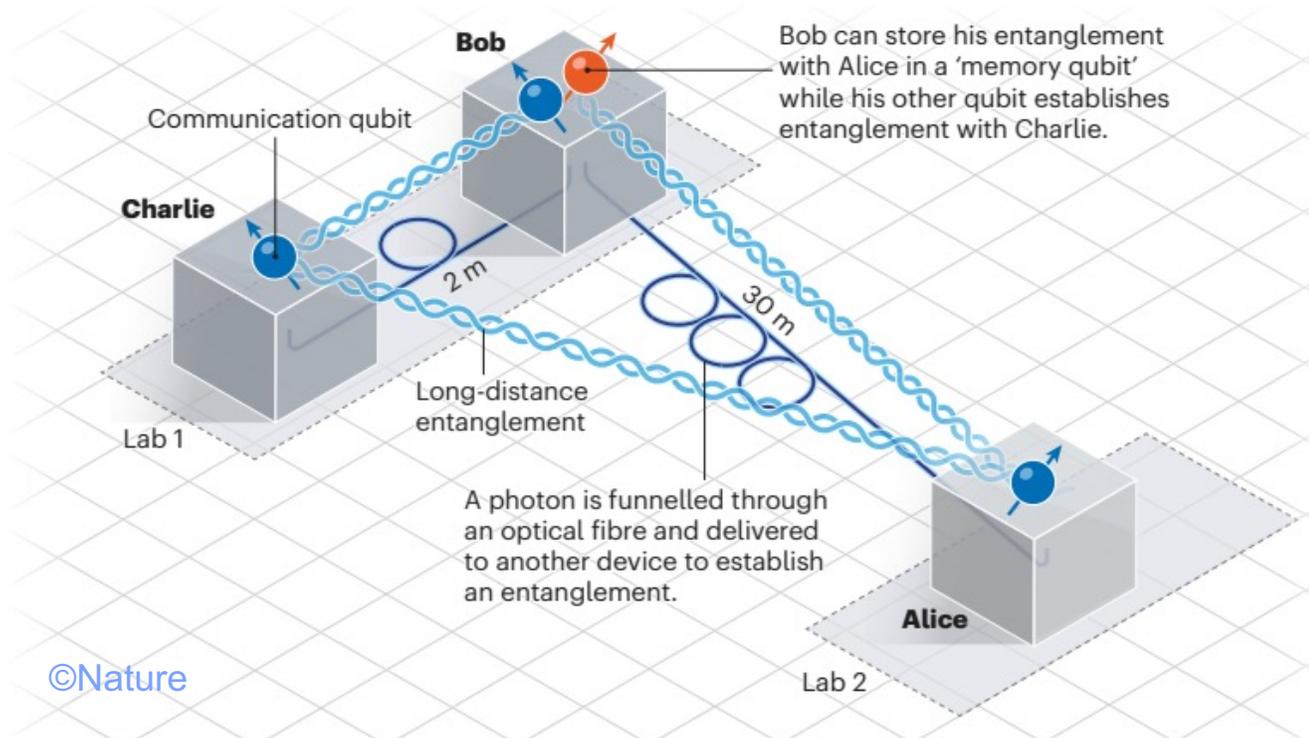


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What is Quantum Internet

QUANTUM NETWORK

Physicists have created a network that links three quantum devices using the phenomenon of entanglement. Each device holds one qubit of quantum information and can be entangled with the other two. Such a network could be the basis of a future quantum internet.



Realization of a multinode quantum network of remote solid-state qubits

M. POMPILI, S. L. N. HERMANS, S. BAIER, H. K. C. BEUKERS, P. C. HUMPHREYS, R. N. SCHOUTEN, R. F. L. VERMEULEN, M. J. TIGGELMAN,

L. DOS SANTOS MARTINS, [...] R. HANSON +3 authors Authors Info & Affiliations

SCIENCE · 16 Apr 2021 · Vol 372, Issue 6539 · pp. 259-264 · DOI: 10.1126/science.abq1919

nature

Qubit teleportation between non-neighbouring nodes in a quantum network

S. L. N. Hermans, M. Pompili, H. K. C. Beukers, S. Baier, J. Borregaard & R. Hanson

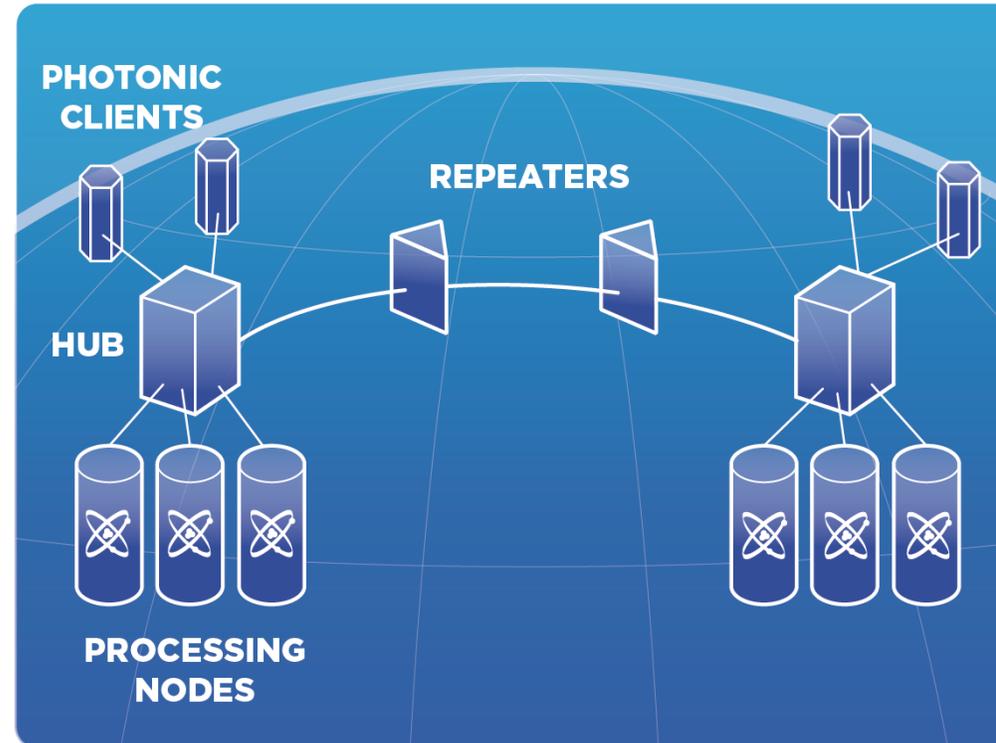
Nature volume 605, pages 663–668 (2022)

<https://doi.org/10.48550/arXiv.2110.11373>

In March 2021, Ronald Hanson's group (@QuTech) Built the first entanglement-based network connecting multiple quantum processors that can produce entanglement on demand

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Fully programmable quantum network prototype connecting two metropolitan scale networks by a long-distance fiber backbone using quantum repeaters



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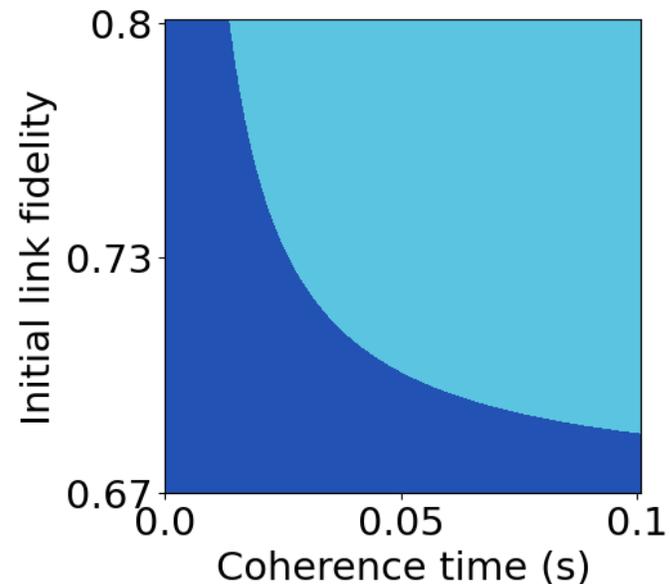


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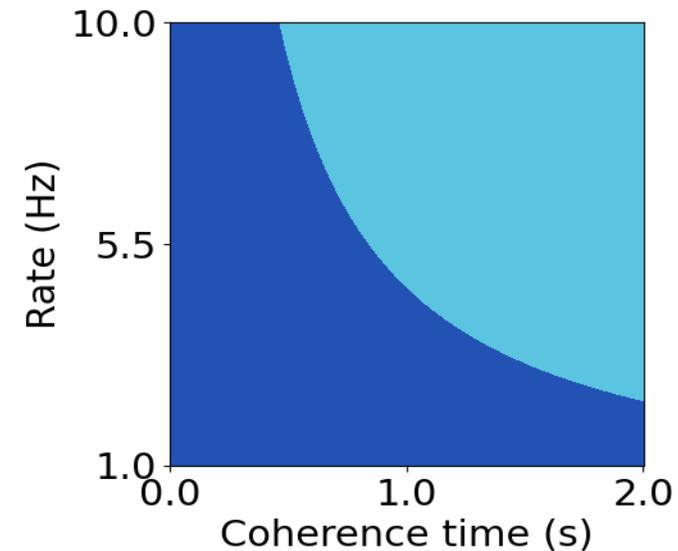
QIA main goals I

Two test protocols to inform technical requirements

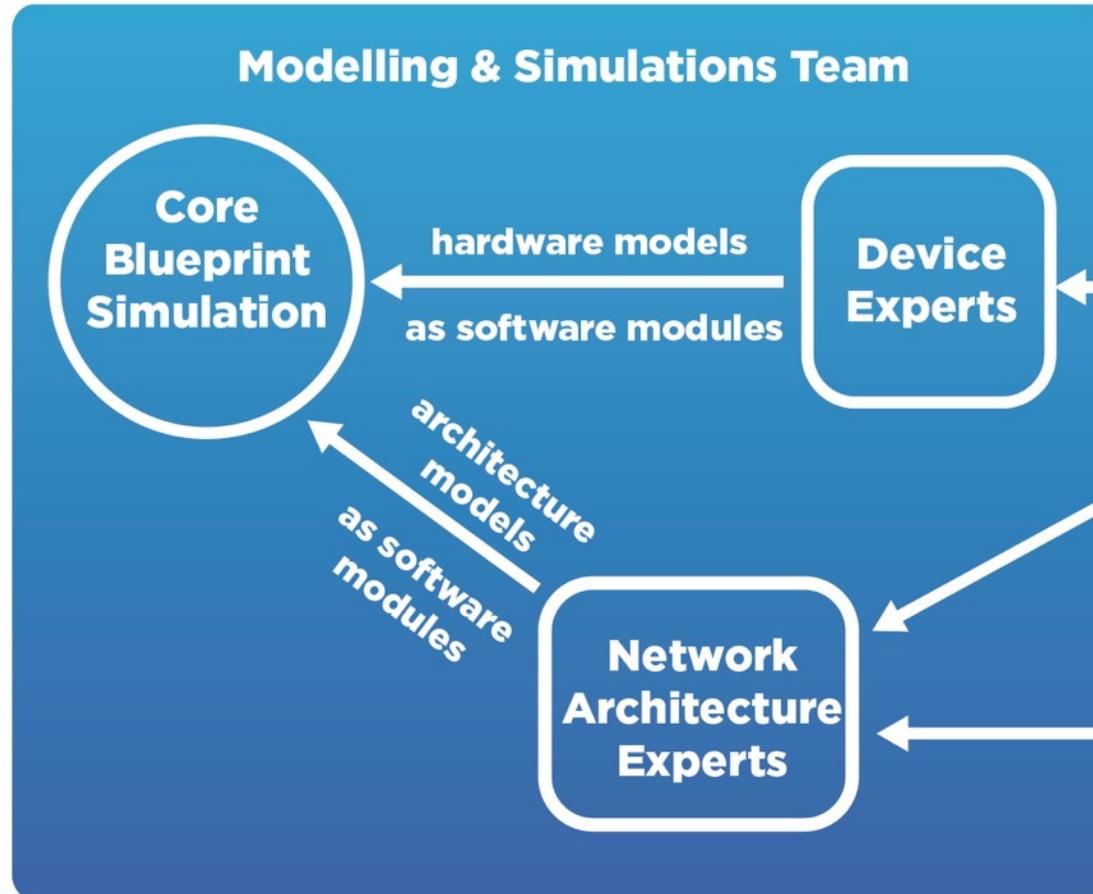
Deterministic Teleportation



Blind Quantum Computation



Modelling and Simulation

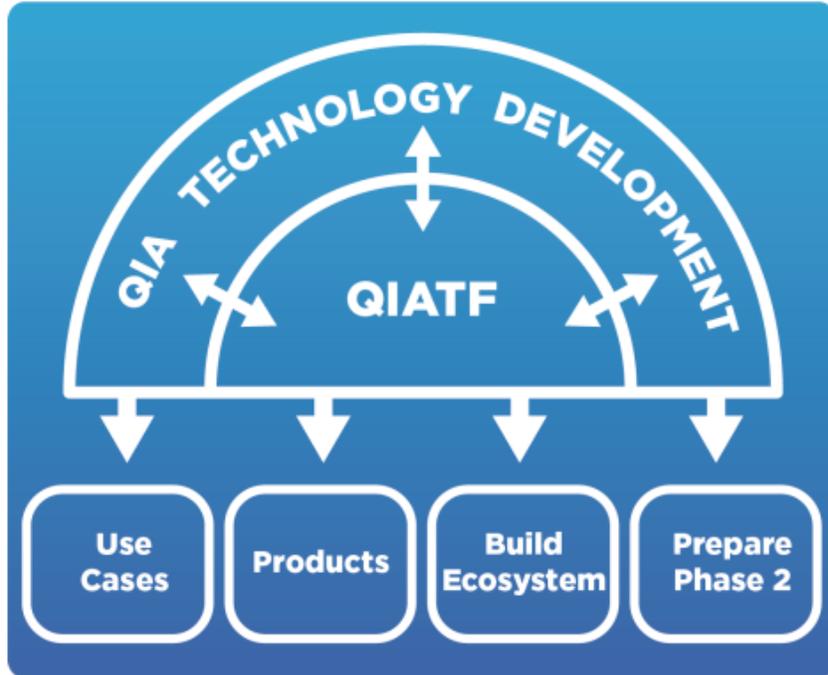


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Innovation & Outreach



QIA Technology Forum (QIATF)

I N S I D E™
**QUANTUM
TECHNOLOGY**
— THE HAGUE —

March, 2023

<https://iqtevent.com/thehague/>

- Translate technology development into future European products and services.
- Strengthen the European Quantum Industry
- Develop quantum competences and skills across industry and academia in the EU



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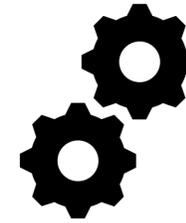
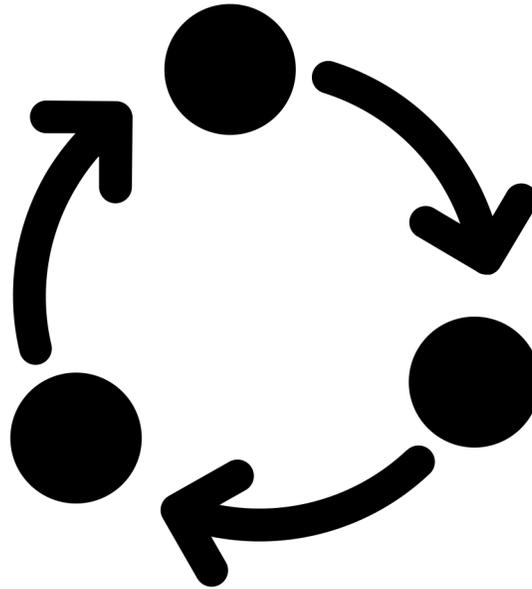
Use Case Team

- Community specialists
- Application & protocol experts



- Describe & Analyse use cases
- Matching applications & protocols

- Engage & interact with potential users
- Identify high level use cases



- Develop code in SDK
- Simulations



- Validation of results



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Simulation & analysis



Software packages (SDK)

- netqasm - for writing application code
- squidasm - for simulating quantum networks
- gne-adk - for interacting with the QKD hardware

Web platform

- Website (www.quantum-network.com)
- Application library
- Simulation and animation
- Execution on real hardware (when available)

<https://www.quantum-network.com/>



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Quantum Internet
Hackathon 2022

Take part in the Quantum Internet
Hackathon

1 – 2 december 2022

More information at:

<https://labs.ripe.net/author/karla-white/take-part-in-the-quantum-internet-hackathon-2022/>

