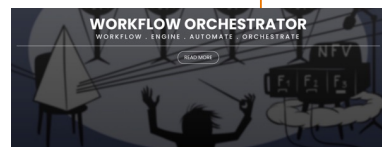


1

Key Takeaways

- Physics of the quantum layer poses the most complex problems. Service integration into existing networks and their operations is a good runner up.
- Eco system of hardware and protocols in support of quantum internet will be in flux for many years.
 - NOs and SPs challenge is to select the right technology and be confident implementing
- Architecture and partial blue prints exist.
 - Details will result in operational complexity and differs from existing conventions
- Quantum Internet infrastructures and its services can be emulated now using
 - existing automation and orchestration software,
 - a configurable control plane
 - NetSquid simulator for the physical layer.



2

2

Introduction Quantum Internet – Use Cases

- The quantum internet extends the existing internet and aims to facilitate the transfer of quantum information for e.g.:
 - Secure generation and dispersion of key material to protect information
 - Remote and secure execution of quantum programs on quantum computers.
 - Improving the performance of quantum-networked sensors and detectors
 - Transport quantum information from quantum sensors into quantum computers and annealers
 - Secure positioning systems
 - Secure exchange (use) of data and destruction of data
 - Quantum clocks

The introduction of use cases and technology will be analogous to the way the internet of things, augmented reality, and tactile internet are and will be introduced.

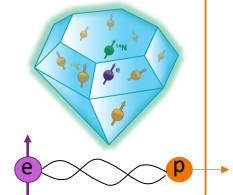
3



3

Introduction Quantum Internet – Needed Efforts

- A **quantum physical layer** for qubits transport and entanglement generation
 - Physicists and information scientists investigate end-to-end generation of entanglement and improve its characteristics.
- **Control layers** assures link, network and application layers **interwork** to optimally use entanglement resources over **multiple domains and infrastructures**.
 - Network specialists design e control planes connecting the quantum physics from the physical layer and quantum processing capabilities from the application layer.
- **Automation & Orchestration** deploys and assures **quantum enabled internet services** work in a proper way for end users by commissioning and provisioning resources from the quantum and conventional technology domain.
 - Service architects and dev-ops experts formulate domain abstractions and resources for workflows that result in the supply of a usable quantum internet service.
- Engineering, engineering and some **more engineering!**



4



4

Network Operator's and Service Provider's role:

- Overall Network and Service planning: Life Cycle Management
- Capacity planning and balancing of resources and expected resource utilization
- Fault detection and isolation
 - Alarm monitoring
 - Trouble shooting
- Performance monitoring
- Set service level specifications and service level agreements for reliability and availability
- Configuration (Commissioning and Provisioning)
- Accounting for billing or upholding fair use policies
- Implement security best-practices

Conventional

>1000 photons/bit
400G bits/second
1s measurement time

Quantum

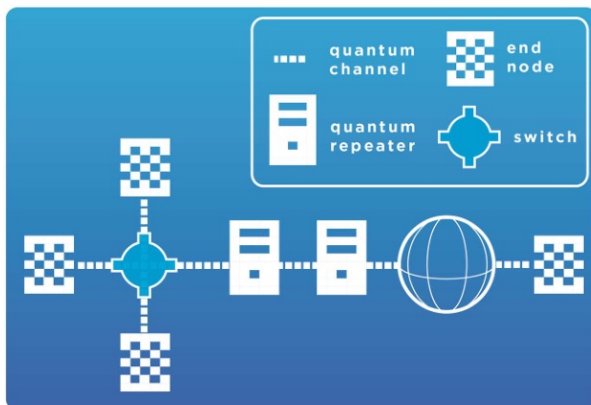
1 photon/qubit
1000 qubits/s
10 years measurement



5

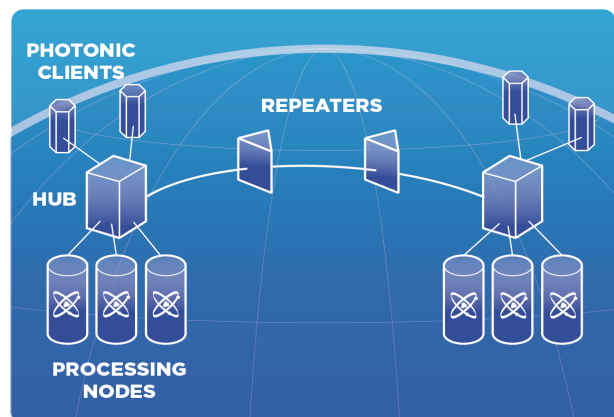
5

Introduction Quantum Internet – Building Blocks



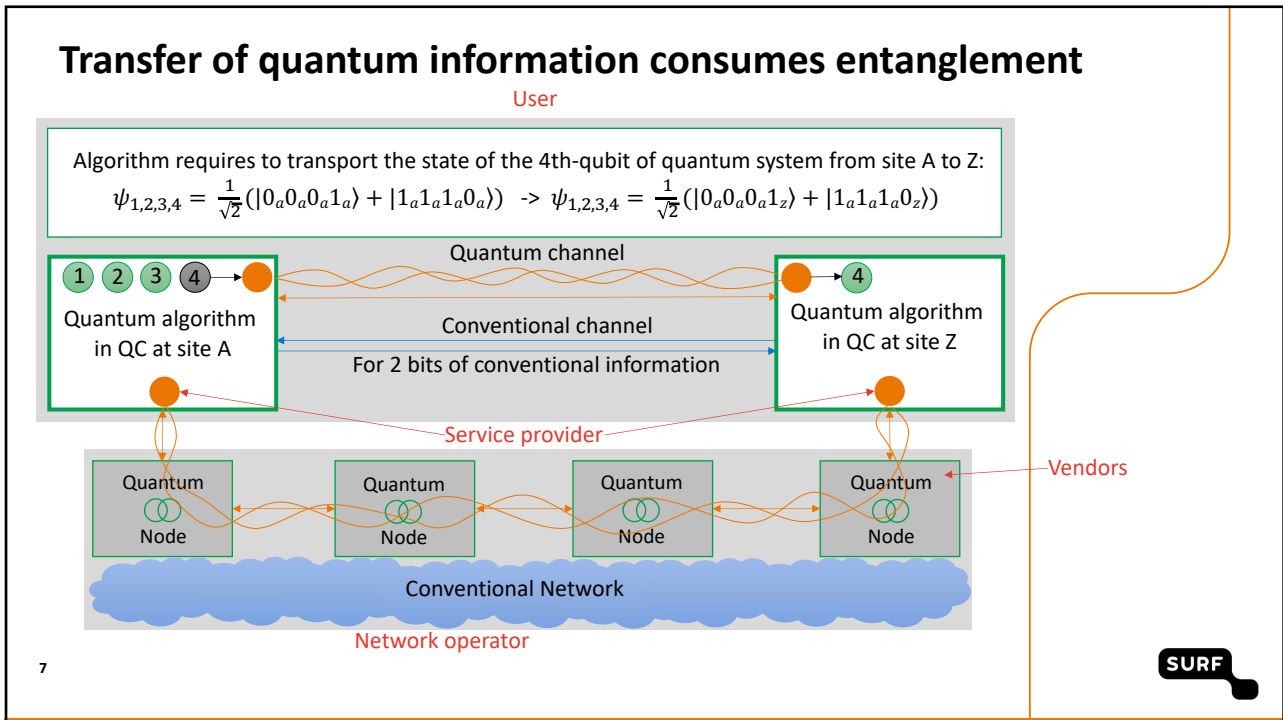
Wehner, Elkouss, Hanson, Quantum internet: A vision for the road ahead - Science 2018

6

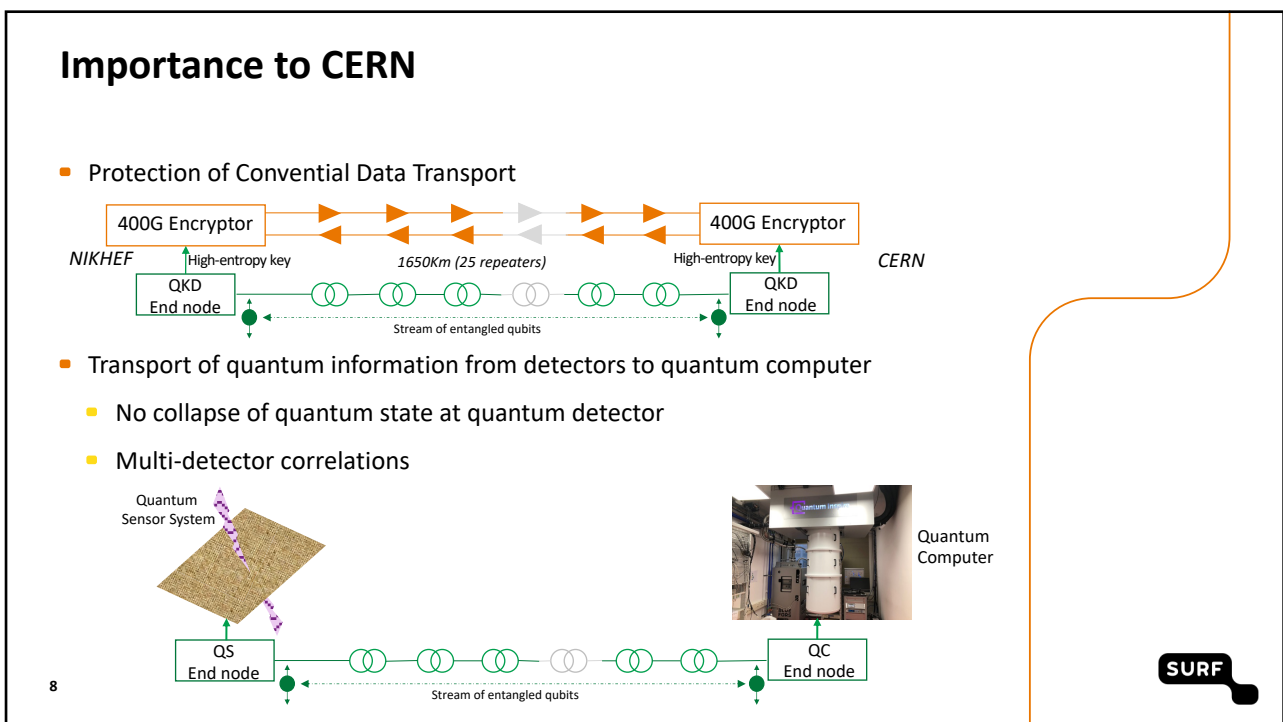


Peter Hinrich – Quantum Internet Alliance presented at RIPE 58, Belgrade, 28th October 2022

6



7



8

Quantum Nodes: Technology is there and will evolve!

Present:

- Quantum Key Distribution using known state of flying qubit and post processing
 - First QKD equipment to market

- QKD using prepare, measure and post processing
 - Entanglement based QKD equipment

Soon:

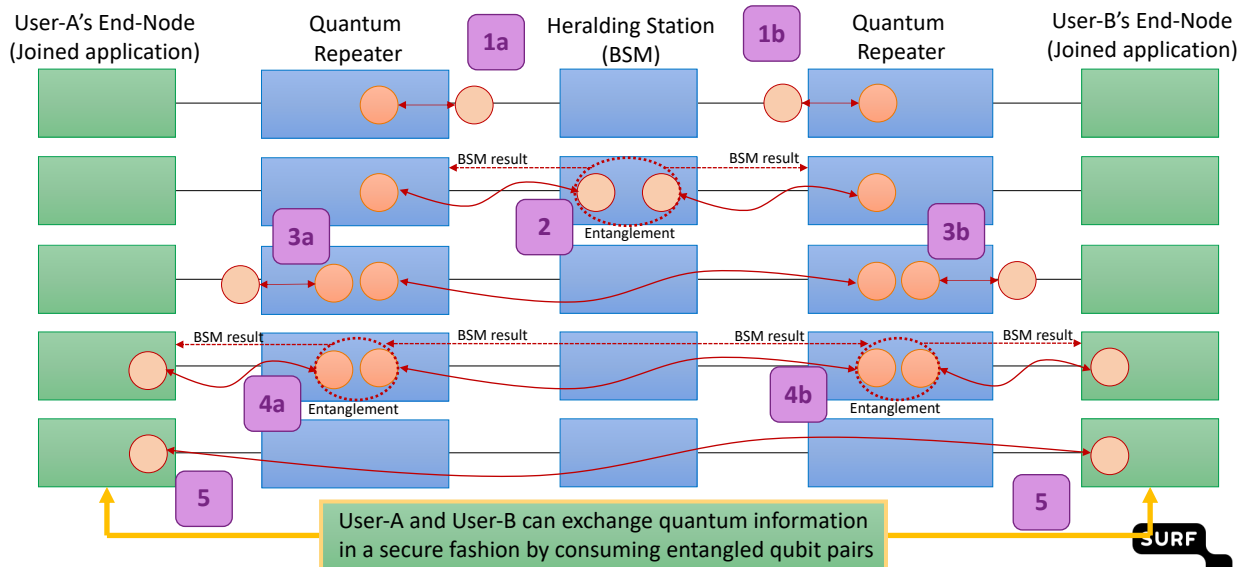
- MDI-QKD and BQC using entanglement, prepare & measure, with post processing and linear heralding

Future:

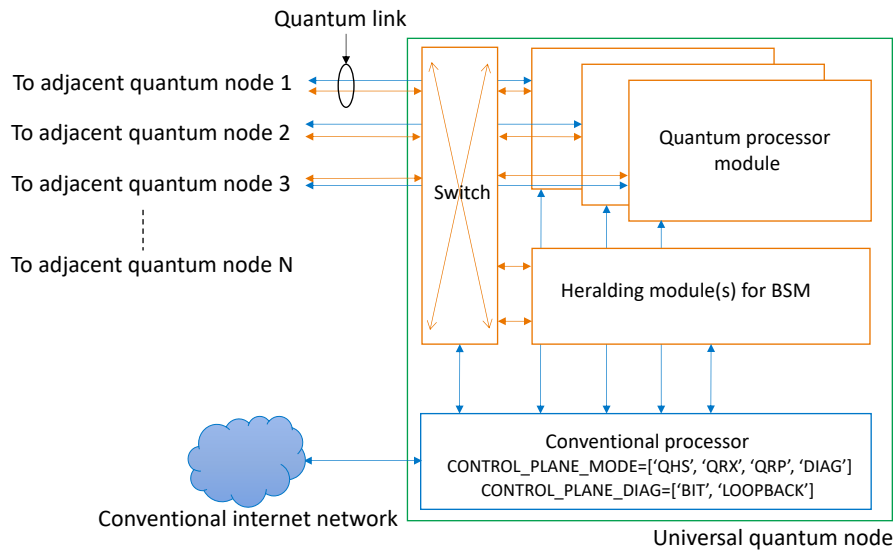
- Quantum repeaters for increasing distance using entanglement swapping and linear heralding
- Conversion of flying qubits to local qubits in a quantum processor
- Quantum memories



Entanglement as a Service / Quantum State as a Service



Quantum Node: A Universal Building Blocks in a Quantum Internet

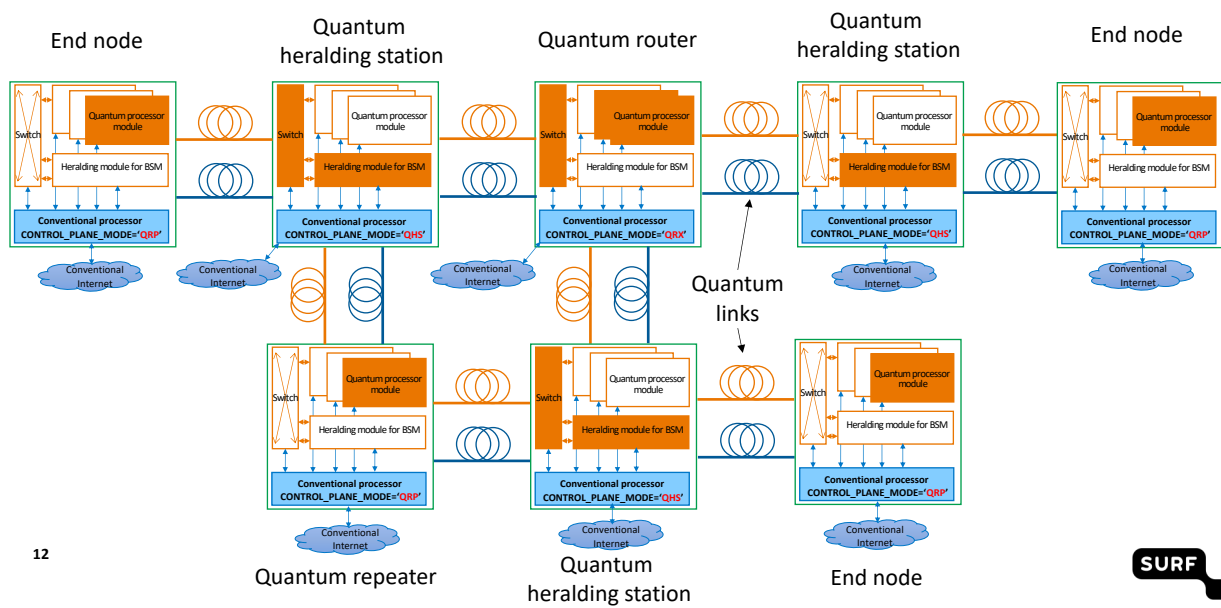


11



11

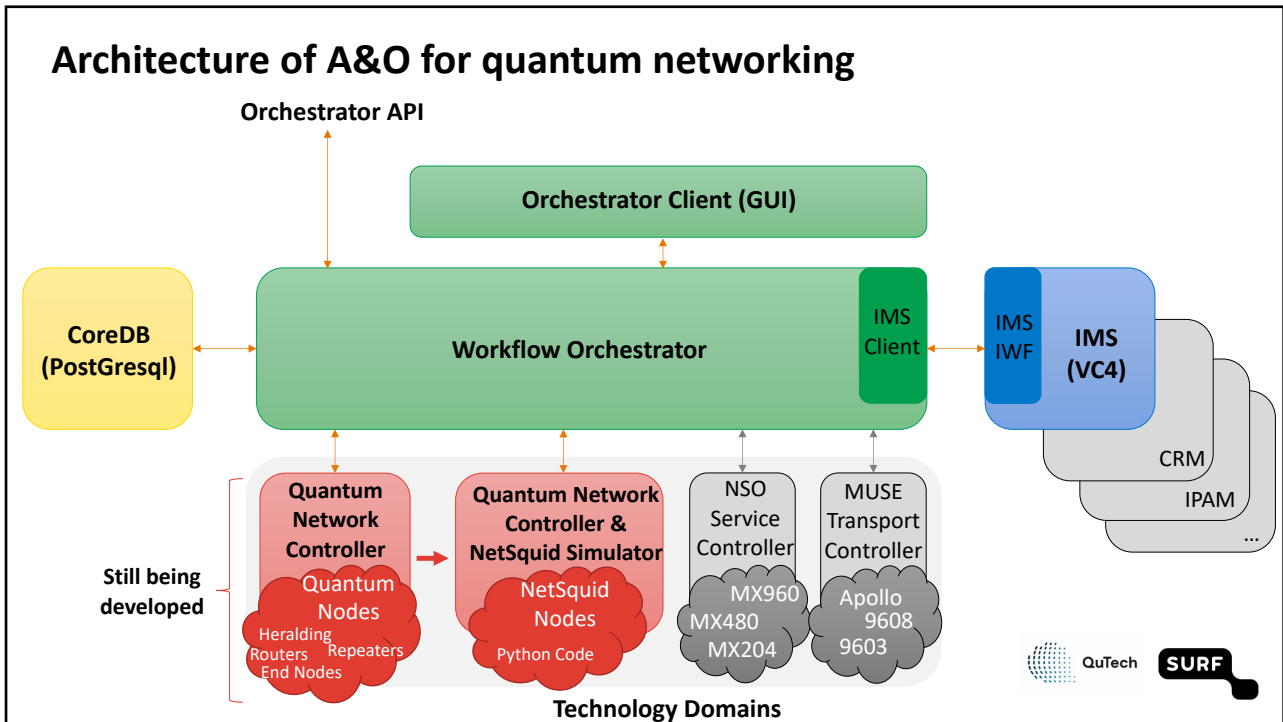
Building blocks of a quantum internet: Universal Quantum Nodes



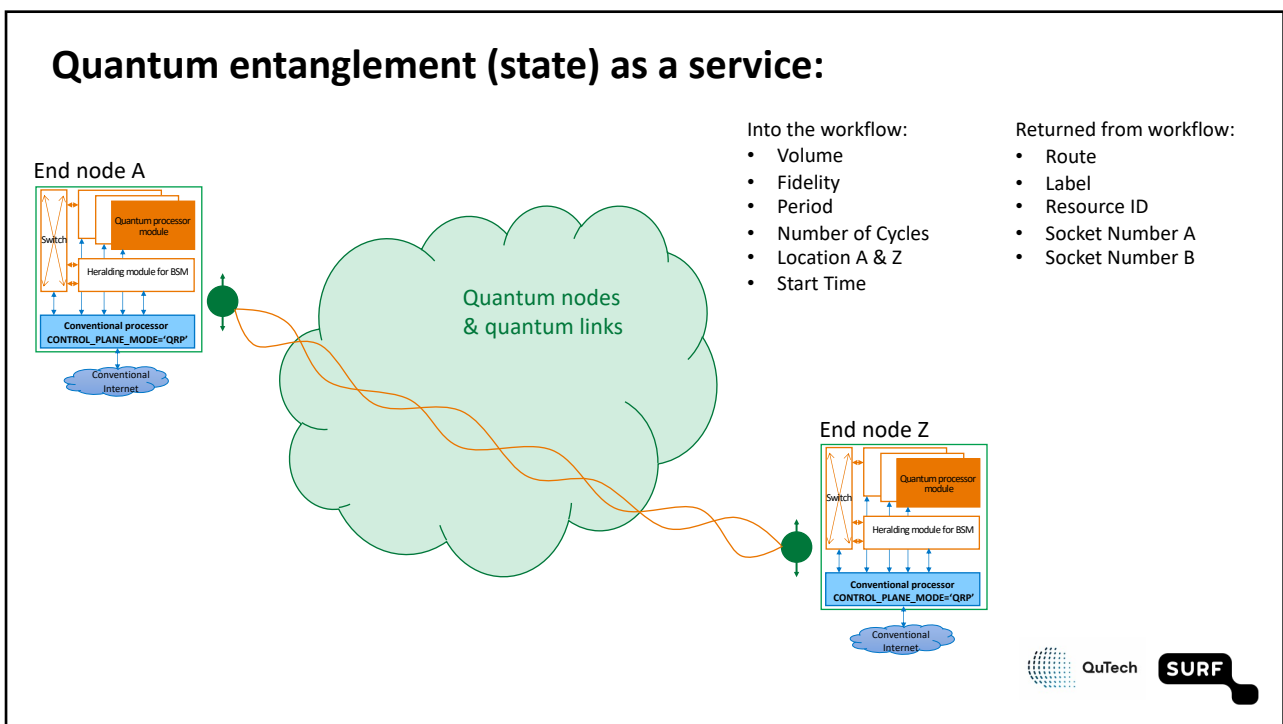
12



12



13



14

A&O of a quantum network and its services

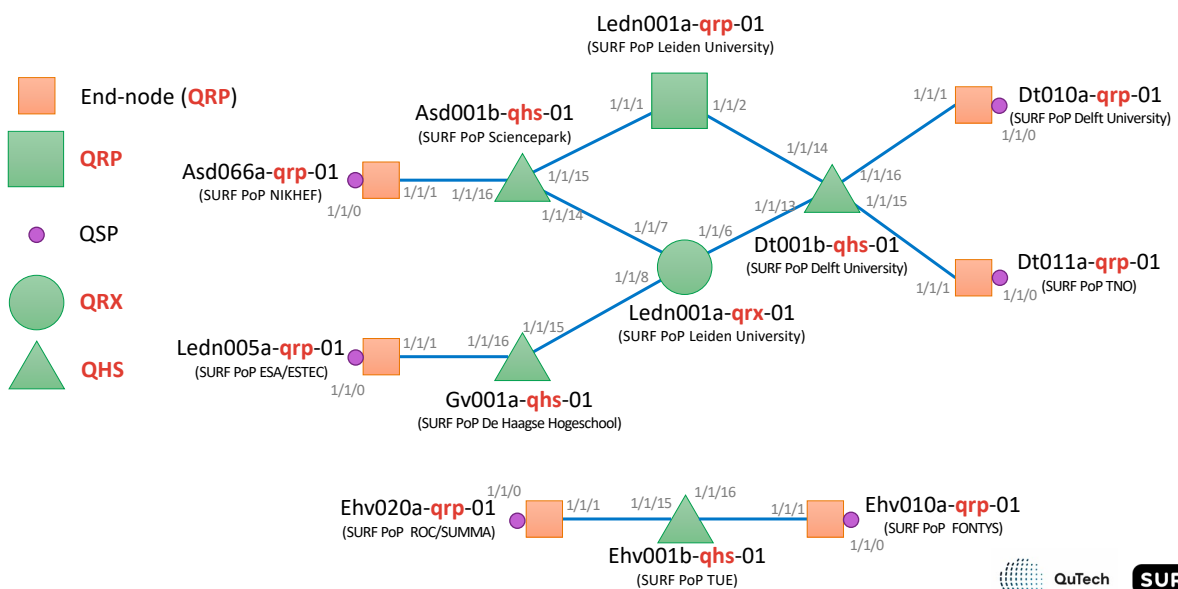
What needs to be done:

1. Create the topology and make sure it is the same in IMS (Inventory Management System) and the QNC (Quantum Network Controller).
 - Create the quantum nodes
 - Create the quantum links
2. Create quantum service ports on the end-nodes.
3. Create Services and their Service Attach Points (SAPs).
 - Entanglement or Quantum State as a Service
 - Quantum Correlation as a Service



15

PoC Quantum Network Infrastructure

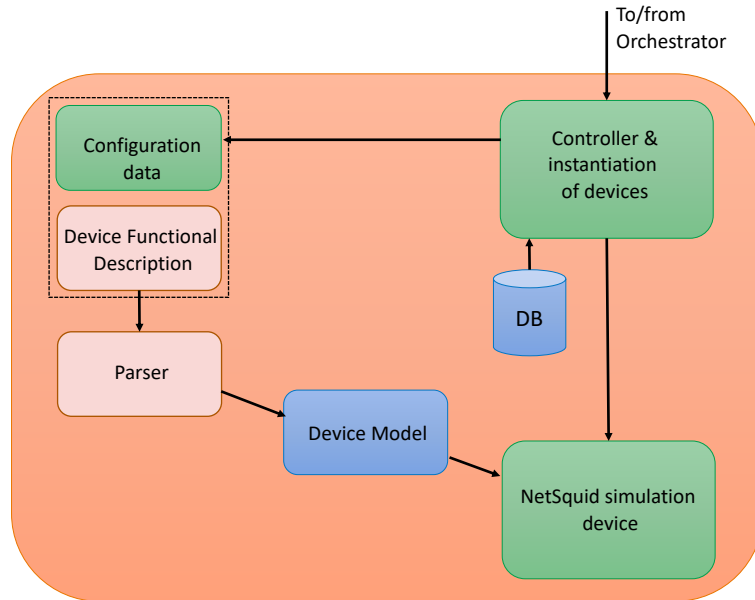


Convention: a-b-c:= Location Code – Type Equipment – Number and x/y/z: x = Chassis or Shelf / y = Slot or Unit / # z = Port or Interface



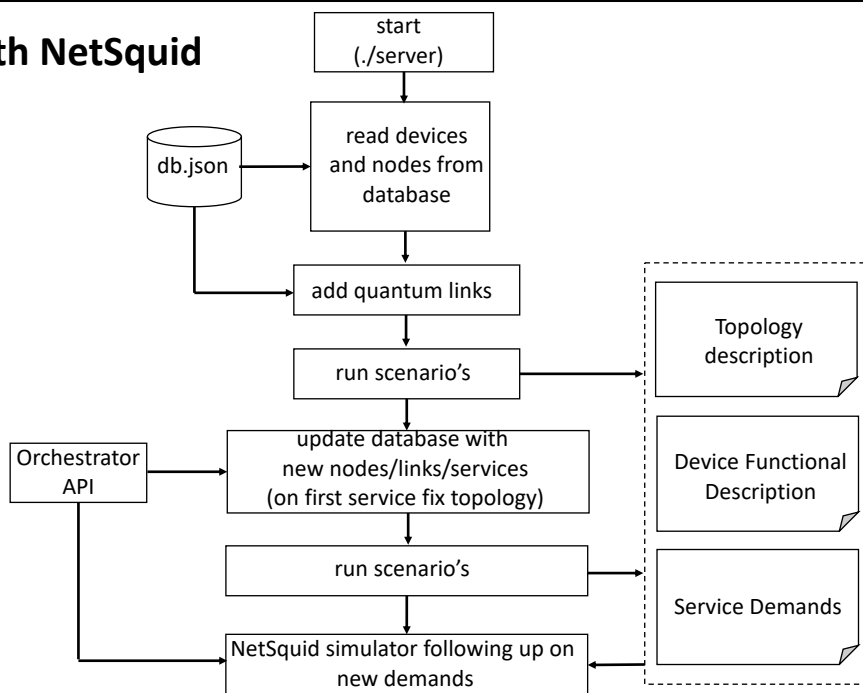
16

Quantum Network Controller with Control Plane and Simulator




17

QNC with NetSquid



18

STAY ENTANGLED!

Rob Smets
E-mail: rob.smets@surf.nl
www.surf.nl
Social media: 

Driving innovation together

SURF

19