A Multiplane Architecture Proposal for the Quantum Internet

draft-lopez-qirg-qi-multiplane-arch-00

D. López, L.M. Contreras (Telefónica),
V. Martín (UPM),
B. López (IMDEA Networks)

IETF#118, Prague (Czech Republic), November 2023

Why an Architecture Framework

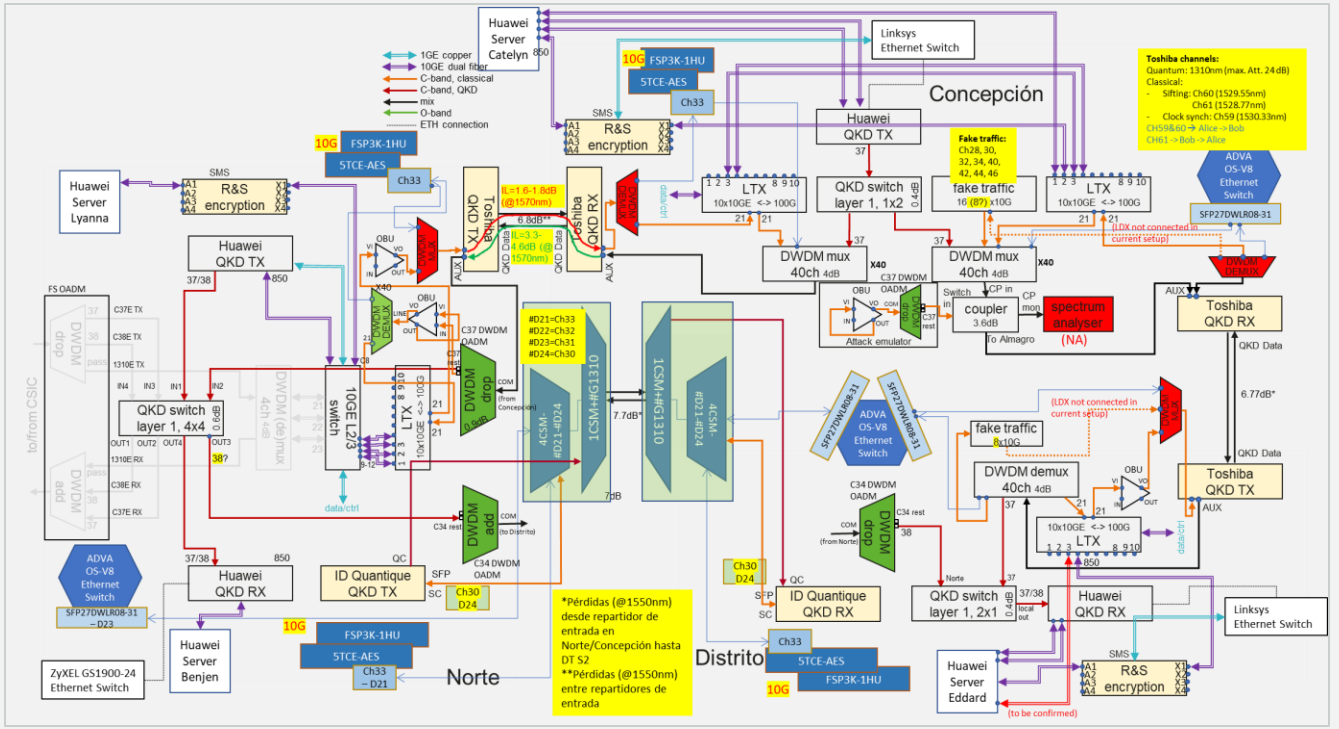
- Provide a reference for further protocol and interface definition
  - Technology evolution
  - The relationships among them
- Seek for the application of architecture principles
  - Foundational ones
  - Operational experience
- Support convergence
  - Use cases
  - Applications
  - Technologies
  - OAM
  - Scale
  - Research effort

Goals and Essential Properties

- The three goals to achieve a Quantum Internet
  - Universality, accommodating any application
  - Transparency, sharing physical media with classical networks
  - Scalability, so quantum networking protocols can support the growth of the network
- Via three essential properties of the framework architecture
  - Agility, with general enough abstractions
    - Avoiding a tight coupling with specific (physical) technologies
    - As they evolve
  - Sustainability, at all levels and in full scale
    - Open availability in technological and economical terms
    - Foster infrastructure reuse
  - Pliability, seamless integration with classical
    - Network operational procedures
    - (Adapted) best practices in use by the Internet community

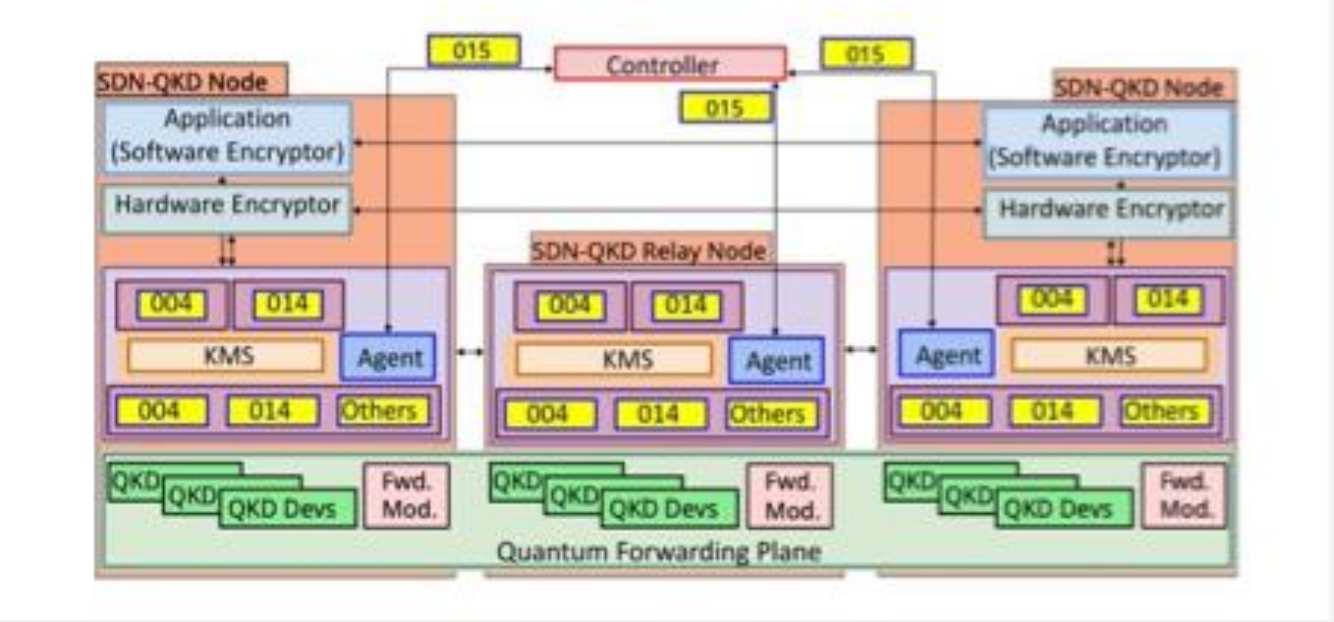
Operational Experience. The QKD Case

- Running infrastructures at a sufficient scale
  - Including (general) users and admins
- Beyond achieving pure quantum communication
  - Application interaction
  - Classical infrastructure
  - OAM issues



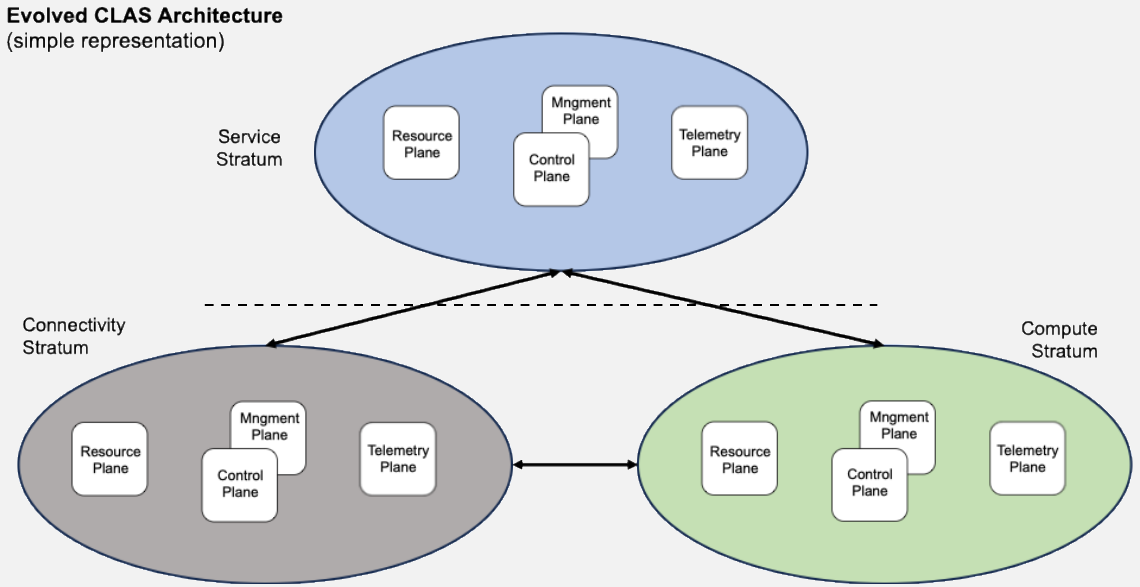
A General QKD Framework

- Addressing matters related to
  - Interfacing applications
  - Service semantics
  - Operational issues
  - Interaction with classical networks
- Three planes
  - The QFP (Quantum Forwarding Plane) ensures the forwarding of quantum signals or enable the utilization of persistent quantum resources
  - The SOP (Service Overlay Plane) supports the use of the keys derived from the QFP by applications
  - The CMP (Control and Management Plane) is made of the elements that create and supervise network state. Based on SDN



Generalizing. The CLAS Architecture

- Cooperating Layered Architecture for Software-Defined Networking (RFC8597)
- Leveraging SDN concepts to address
  - Service provisioning and capabilities offered to applications
  - Data transfer among endpoints
- Structured around strata, with a regular set of planes
  - A further extension under discussion within COINRG
- Essentially compatible with the architectural lessons learned within the QKD fields
  - Stronger formalization and alignment with OAM best practices
- Integration of control mechanisms, and the interplay with the (shared) infrastructure
- Incorporate general trends
  - Cloud nativeness
  - Zero-touch management
  - Intent



CLAS Strata for Quantum Networks

- A Service Stratum, dealing with the functionality related to the purpose of the quantum network
  - Generation of management of keys in QKD
  - Others: time synchronization, identity assurance, sensing…
  - Entanglement distribution in a general quantum network
- A Quantum Forwarding Stratum, in charge of the direct application of quantum protocols and algorithms
  - Between any two endpoints of a quantum link
  - Even when it is a multi-hop one, whatever the nature of *repeaters*
- A Connectivity Stratum, taking care of providing the paths to support the quantum links
  - Supported by OTN infrastructure, via fiber and/or open-space links
  - Follow a common connectivity paradigm
  - From current circuit-based approaches to any other potential *classical encapsulation*

What We Have

- Incorporated operational experience with QKD networks
  - With some relevant additions
- Provided additional degrees of freedom
  - Independent resource and control planes at each stratum.
  - Support the coordination of different strata via SDN
  - Different aggregation patterns: multi-stratum, multi-domain…
  - Different models: federated, hierarchical…
  - Focus on agility
- Addressed current trends to network automation
  - Whatever the flavor including AI and intent expressions
  - In support of pliability
- Considered issues related to the connectivity of quantum links
  - And its interaction with the support of quantum network services
  - Address sustainability goals

And What Comes Next

- Identify interfaces and protocols
  - Among current proposals
  - And potential gaps
  - A framework, not a solution
- Explore the implementation side
  - As a combination of real, emulated and simulated components
  - Along the NDT approach
- Gather QIRG comments and support
  - And make this a useful reference for the coming QI