HellasQCI - Quantum Communication Infrastructure for Greece

QCI Days in Athens 2025 Demonstration: Cross-border collaboration between Greece (HellasQCI), Austria (QCI-Cat) and Spain (EuroQCI Spain)

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Dr. Konstantinos Tsimvrakidis, NKUA

GÉANT Quantum Infoshare

"*Operational Aspects of Quantum Communication Networks*",

02 September 2025

Overview of the presentation

- The HellasQCI project: brief overview
- QCI Days 2025
- The Athens Quantum Network – QCI Days 2025 demonstration

EuroQCI - Status in Greece

HELLENIC REPUBLIC
Ministry of Digital Governance

grnet

EuroQCI

The **MinDig** signed the **EuroQCI Declaration** (2019)

EuroQCI is part of the **Digital Transformation Strategy of Greece** (2020-2025)

Greece signed the **European Declaration on Quantum Technologies** (2023)

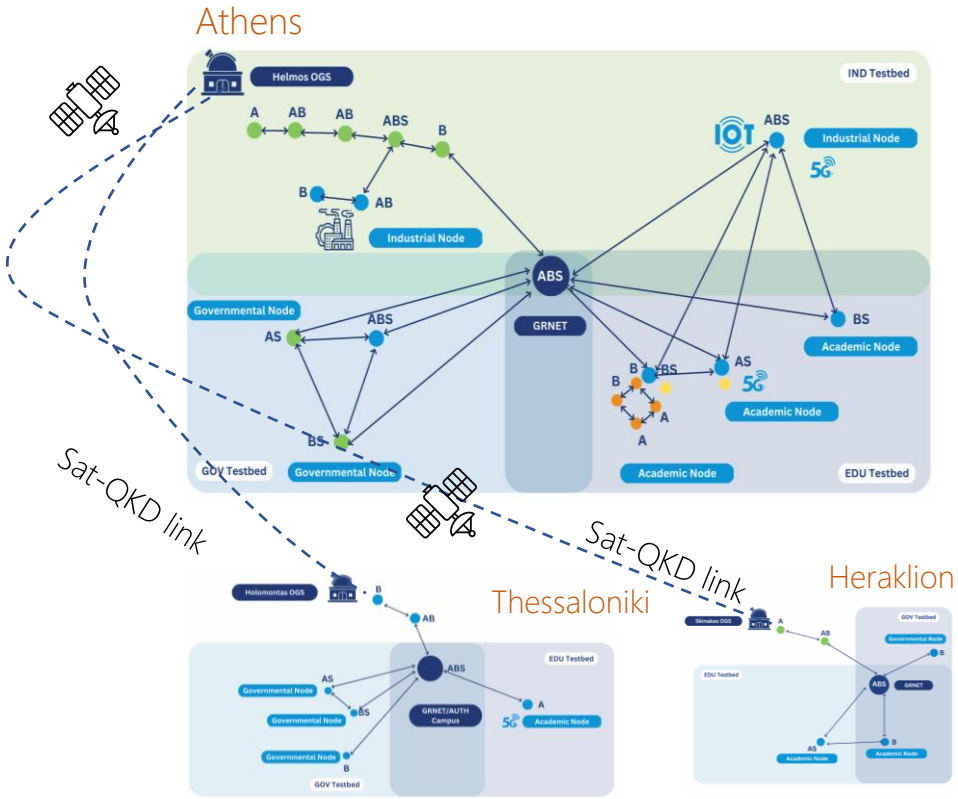
EuroQCI is part of the new **Digital Transformation Strategy of Greece** (2025-2028)

Includes GR's participation into the **EuroQCI CEF** call & the **EuroQCI Iris²** calls

Greece is preparing its **National Quantum Strategy**

readiness for the upcoming **EU Quantum Strategy** and **EU Quantum Act**

HellasQCI - National pilot QKD terrestrial backbone networks



Deploy the national pilot quantum networks as part of the EuroQCI	• **3 national MAN test-sites (240km)**: Athens, Thessaloniki, Heraklion-Crete • Connecting geostrategic locations in Greece • **Terrestrial connectivity to 3 Observatories** (OGSs) to the closest MAN QKD network **(410km)**
Powerful MAN test-beds	• **3 domains:** GOV, IND, EDU | **27 Total QKD Nodes:** permanent & no-permanent → **Use Cases / Trainings** • **Permanent QKD nodes:** 13 GOV/NSA, 7 EDU and up to 4 nodes for the entanglement distribution network – **Quantum Internet** (EPPSs & SNSPDs)

HellasQCI Architecture

→ HellasQCI Architecture 3-layer format

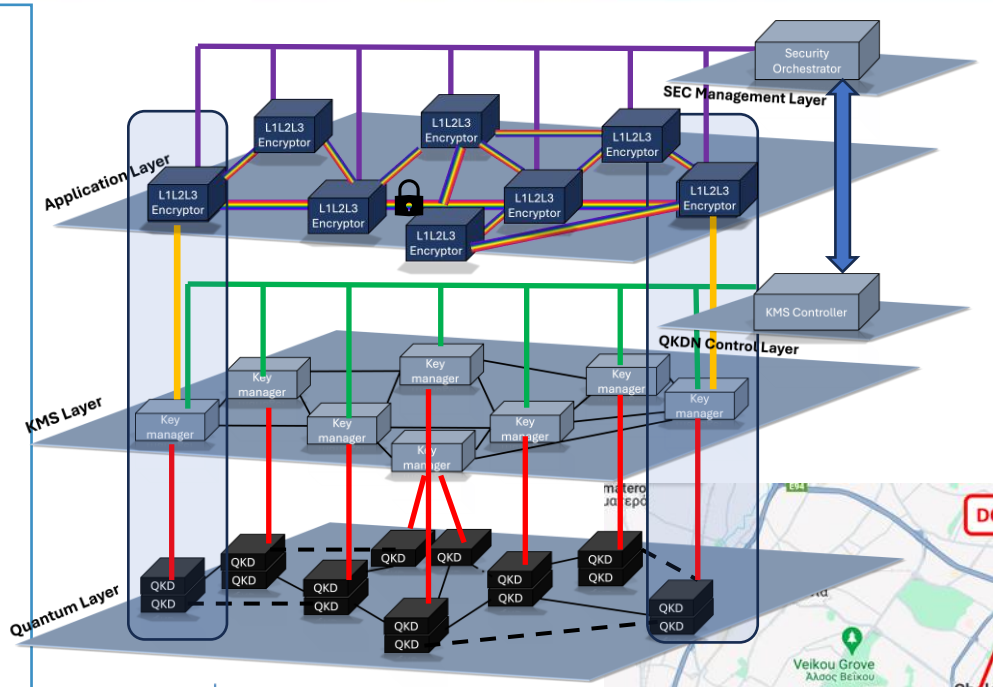
QKD layer
Support relayed DV-QKD, switched QKD, support partial mesh deployment for optimized usage

KMS layer
Link with Application Layer
(Support functions of ETSI-GS-QKD-018)

Perform advanced QKD-SDN controls
(Support functions of ETSI-GS-QKD-015)

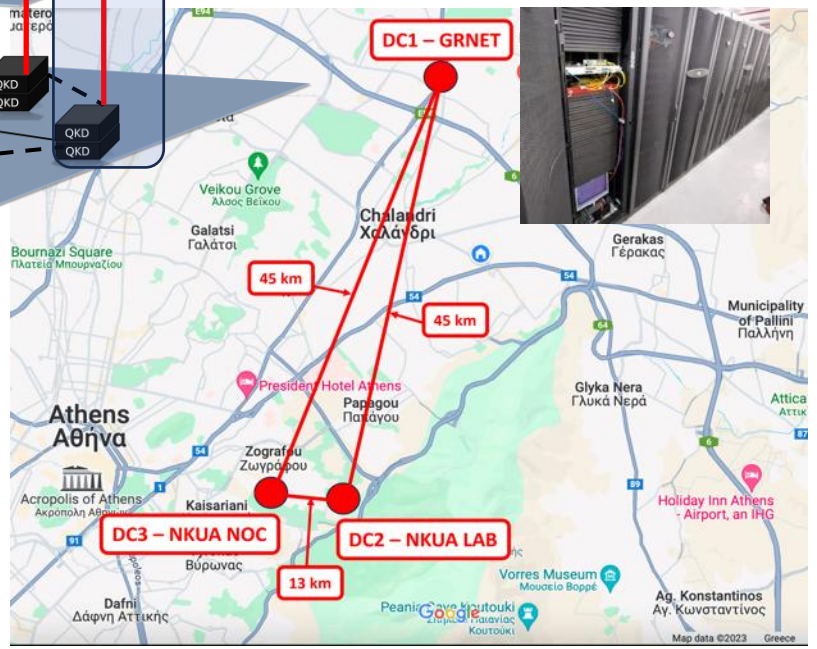
Transparency with QKD vendors
(Support ETSI-GS-QKD-014 for QKD keys interface)

Application (Service) layer
L1, L2, L3 encryption + Maintain backwards compatibility with classical encryption schemes



ECOC2024 FRANKFURT

Link



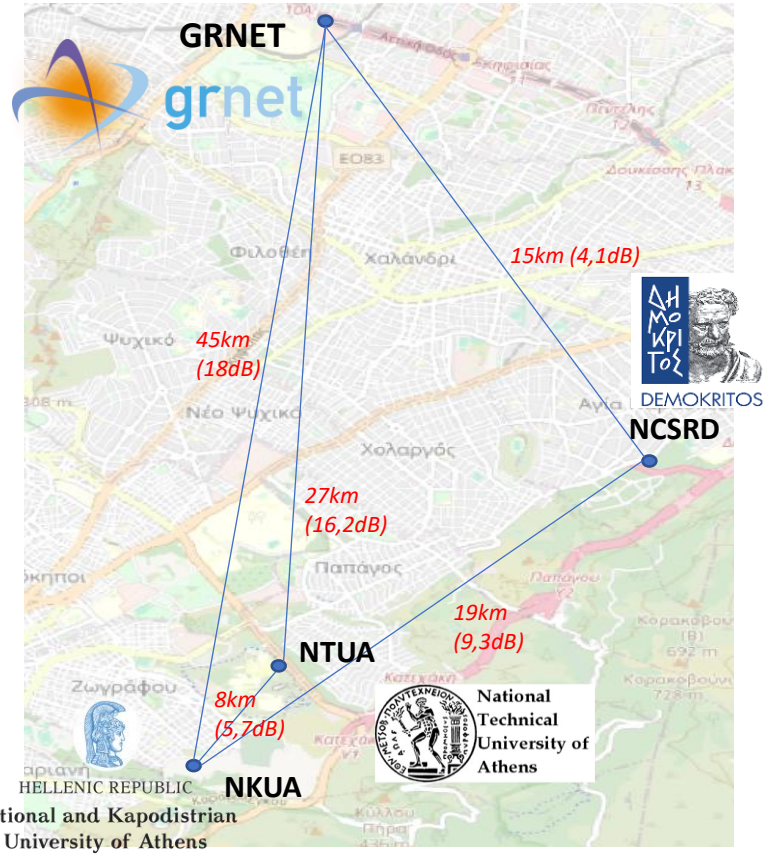
→ PoC validation (45km)

PoC to validate HellasQCI Architecture in a real field deploy testbed (L1-OTN): Complex topology of a 3-node full ring configuration GRNET- NKUA (45km).

PoC key features and innovations: Hybrid operation – SMS orchestrates quantum and classical keys, Supports optimized QKD resources - requires less QKD pairs.

Athens Quantum Network setup - 120km

- Extend to 8 nodes: GRNET, NKUA, NTUA and NCSRD
- 5 physical links – 120km
- To test and accept delivery of the QKD devices / perform use-cases



GRNET - NKUA
Total length: 45km (18db)

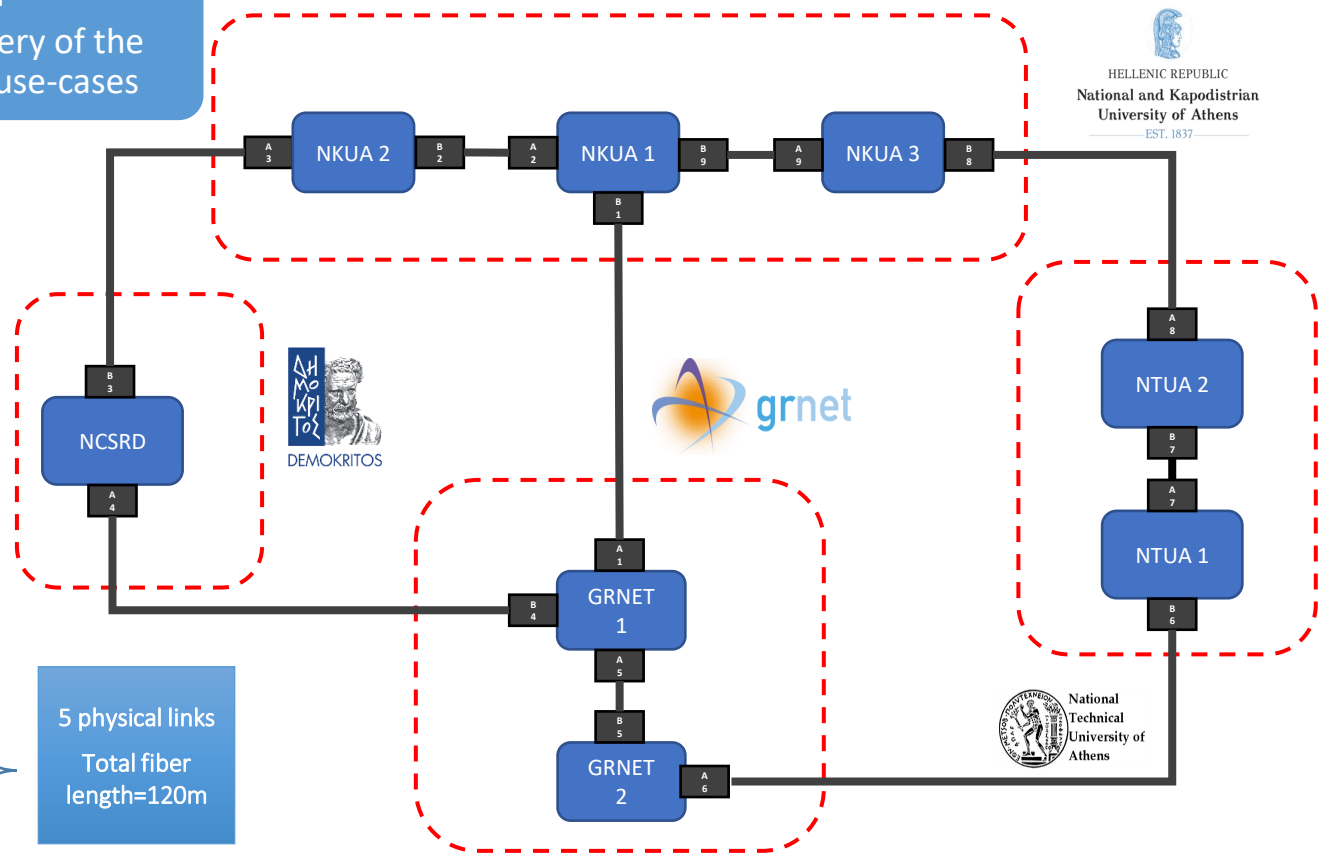
NTUA - GRNET
Total length: 27km (16,2db)

GRNET - NCSRD
Total length: 15 km (4,1db)

NSCRD - NKUA
Total length: 19km (9,3db)

NKUA - NTUA
Total length: 8km (5,7db)

5 physical links
Total fiber length=120m



HellasQCI - Training & EuroQCI participation

- ✓ **Training methodology**: addresses the needs of academic/research staff, experts in digital security, end-users from public and private sector
- ✓ **Two training events already held**: (i) Workshop on QKD Systems & Cybersecurity with QKD and PQC (Athens, 09/23), (ii) Workshop on EuroQCI Deployments and Cooperation & Cybersecurity with QKD and PQC (Heraklion, Crete, 09/24)
- ✓ **50 lessons** performed, **6 labs** took place, **800 total attendees** (online & physical), Visit to **Skinakas OGS**
- ✓ **Final HellasQCI Training Event**: 11/25, Thessaloniki, Workshop on Space-based QKD, visit to **Holomontas OGS**
- ✓ **HellasQCI Training Platform is online**

HellasQCI 4-day Training event in Athens

HellasQCI 2-day Training event in Crete

HellasQCI - EuroQCI participation & Community building

- HellasQCI Consortium Participates at the **meetings of Petrus ETWGs**
- GRNET and MinDig at the **regular meetings of Nostradamus project**
- **Contribution & participation in conferences & workshops** organized by the EuroQCI community
- Establishment of the **HellasQCI community** from all national stakeholders that can benefit and support the HellasQCI networks.
- **Raise Awareness and Ensure better participation** into the EuroQCI and leverage new end-users for the expansion of the HellasQCI networks.
- More than 28 registrations (GOV,EDU,IND) have been attracted so far in the HellasQCI community registry.
- Participation in the **EuroQCI CEF Call** (SEEWQCI, TransEuroOGS).

QCI Days 2025

Event Details

Date: 28–30 April 2025

Venue: Eugenides Foundation, Palaio Faliro, Athens

Key Figures & Participation

On-site Participants: ~300 attendees

Online Viewers: ~300 unique daily viewers via GRNET's DIAVLOS platform

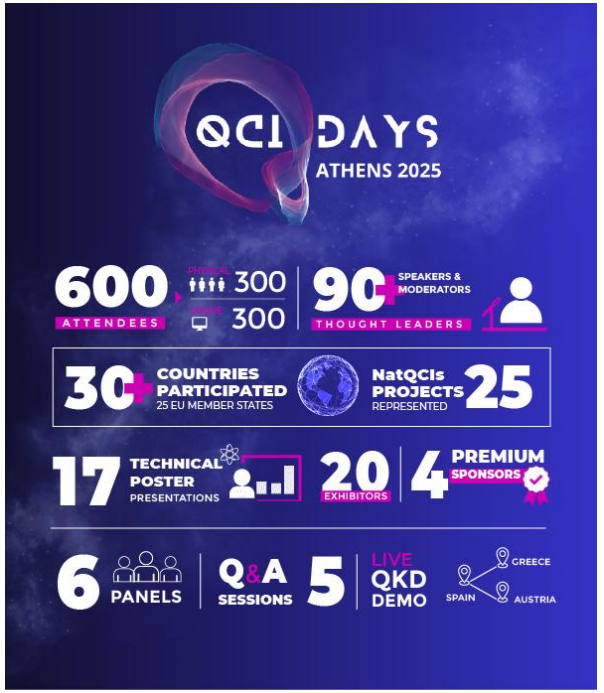
Countries Represented: 30+

National QCI Projects: 25; **Industrial QCI Projects:** 6

Speakers: 90+ and **2 Keynote speeches:** Professor Artur Ekert, University of Oxford and CQT Singapore, and Dr. Eleni Diamanti, CNRS

Exhibitors: 20 technology providers

Panels & Live Q&A: 6 sessions



Press: 81 articles (online and press) + aired on the Greek Public Television - ERT

High-Level Engagement

Participation from the **Minister of Digital Governance** and the **Secretary General of Telecommunications and Posts** responsible for EuroQCI (Greece)

Attendance by the **Head of Unit C.2 – European Commission**, in charge of EuroQCI

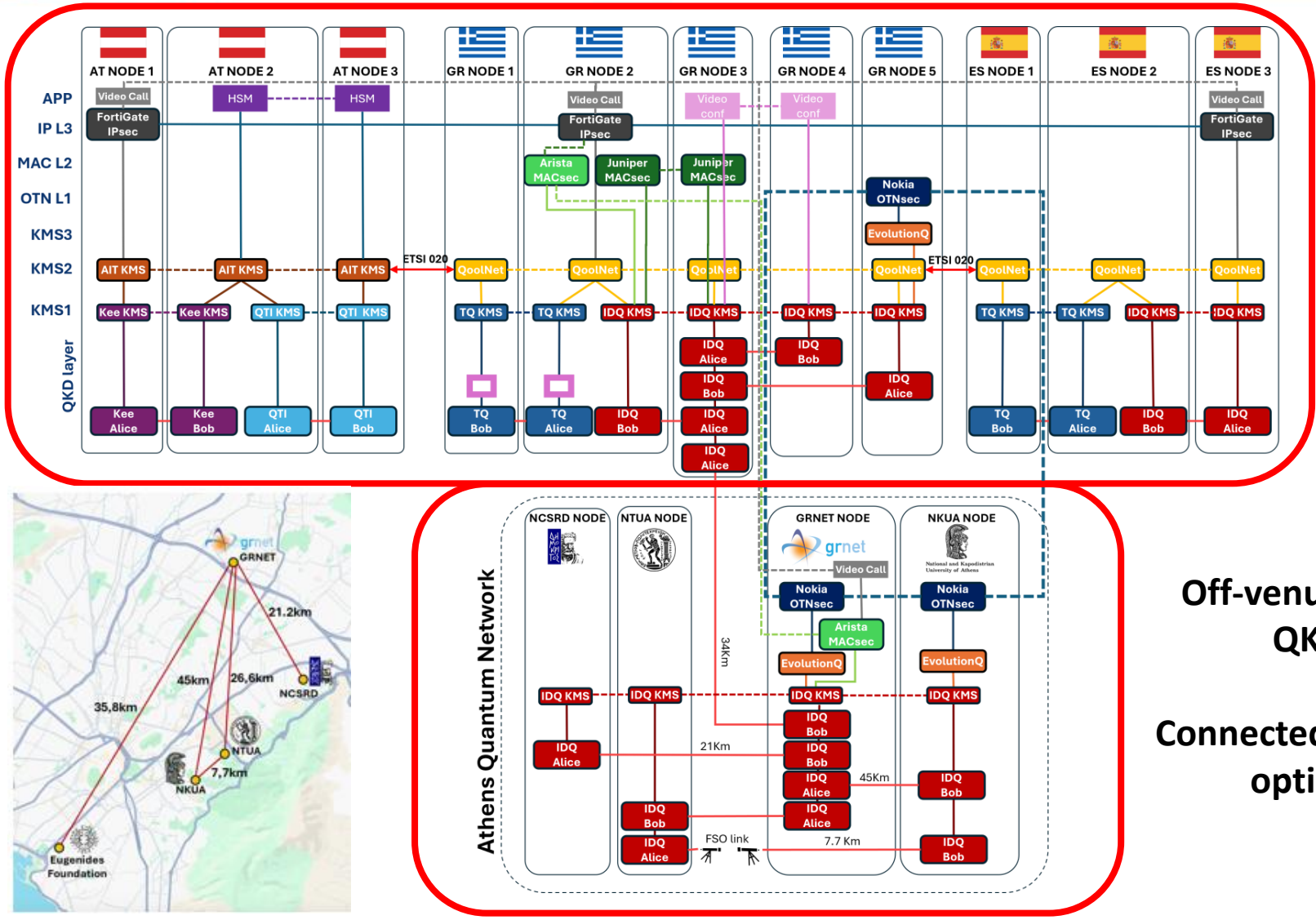
QCI Days 2025 Demo QKD Network

3 QKD nodes

5 QKD nodes

3 QKD nodes

QCI Days 2025 Demo QKD Network



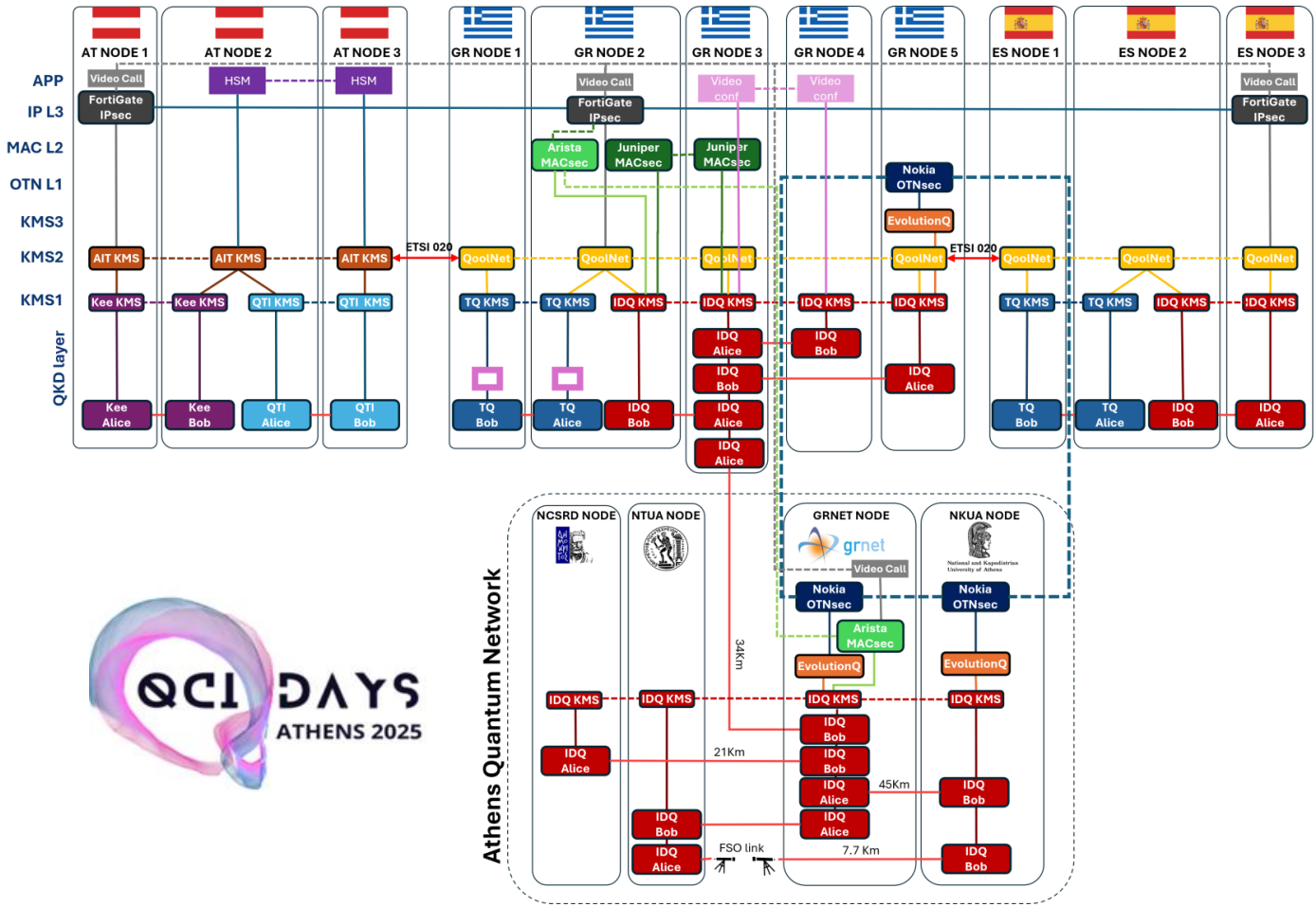
QCI Days 2025 Venue

Off-venue field-deployed QKD Network

Connected through a ~35km optical fiber pair

Demo Overview

- **Multi Node**
  - 11 rack nodes, 4 physical nodes
- **Multi Vendor QKD**
  - ID Quantique, ThinkQuantum, KEEQuant, QTI
- **Multi-layered Key Management**
  - Three layers of KMS
- **Multi-domain**
  - Spanish, Greek , Austrian
- **Multi-service**
  - OTNsec, MACsec, IPsec, Appl. layer
- **Field-deployed segment**
  - Athens Quantum Network (4 nodes: GRNET, NKUA, NTUA, NCSRD)



Demo - Physical Layer

- **DV-QKD: Phase & time bin encoding**
  (ID Quantique Clavis XG)

  IDQ Alice | IDQ Bob

  QTI Alice | QTI Bob

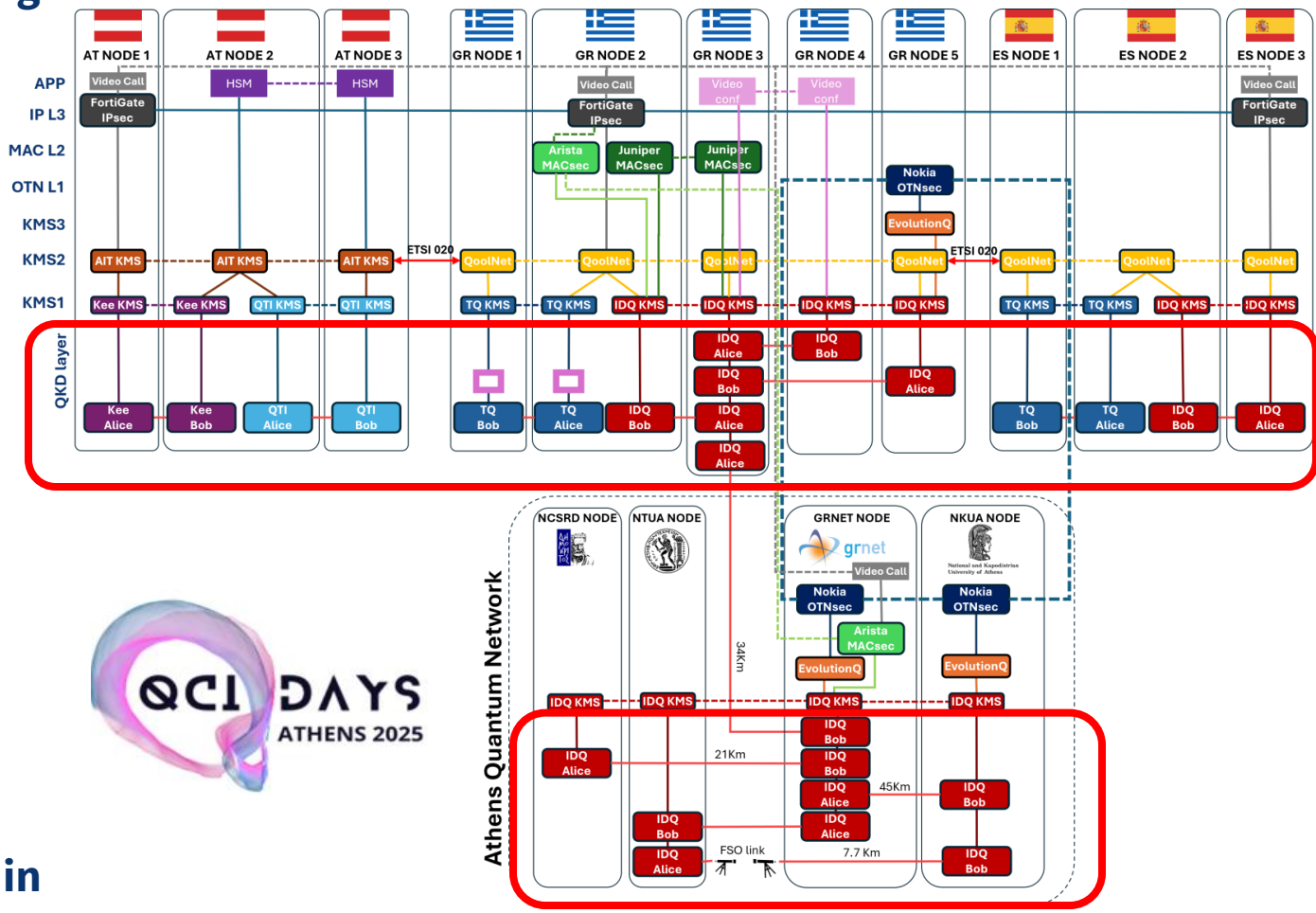
- **DV-QKD: Polarization encoding**
  (ThinkQuantum Quky)

  TQ Alice | TQ Bob

- **CV-QKD**
  (KEEQuant Andariel+KMS)

  Kee Alice | Kee Bob

- **15 nodes, 13 QKD pairs, arranged in Arbitrary Network topology**



Demo KMS Layer & Multi-domain interoperability

- **Multi-layer Key Management System**
  - Embedded & External KMS

- **Proprietary QKD vendor KMSs**
  Interoperable through ETSI-GS-QKD-014

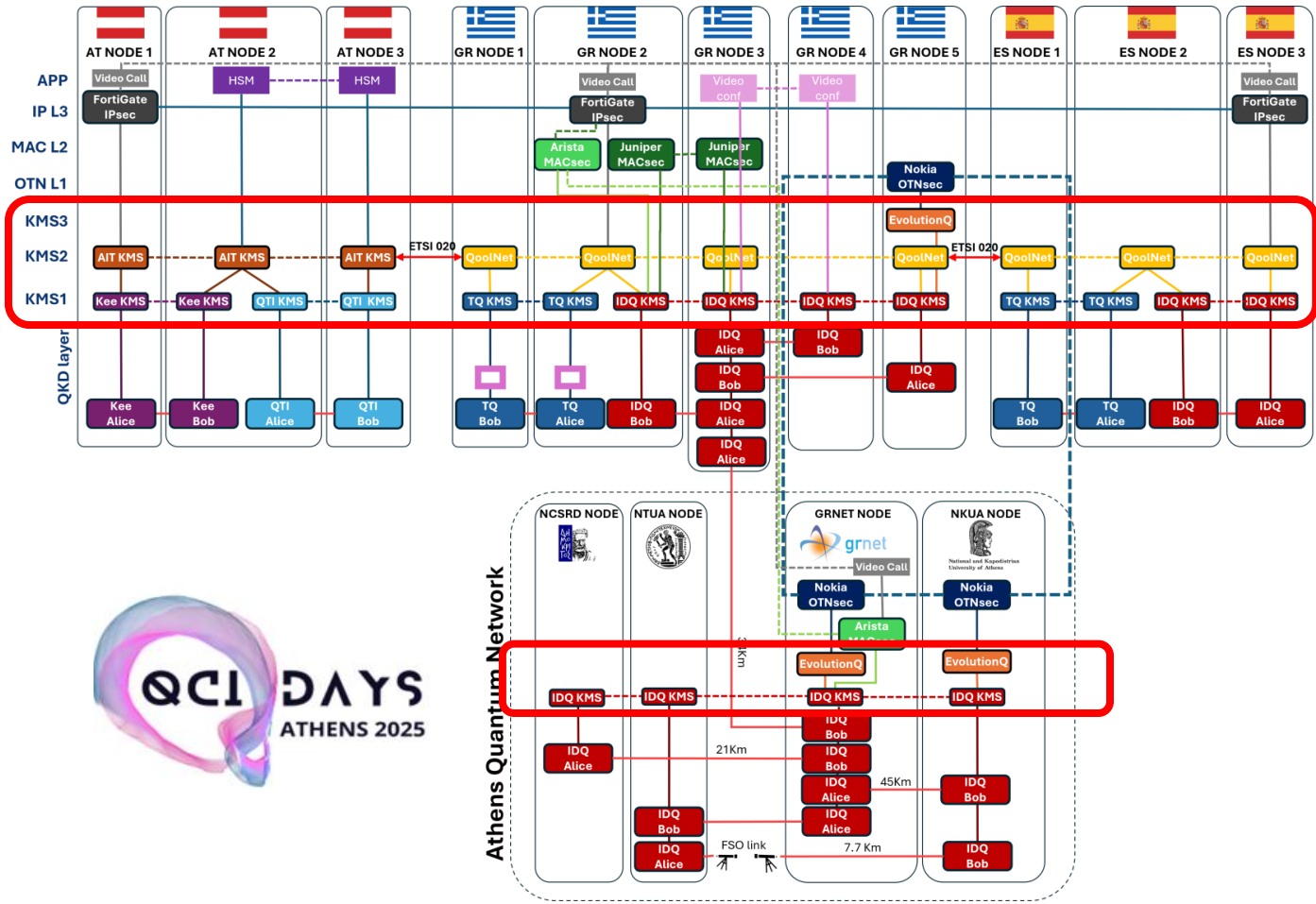
IDQ KMS | TQ KMS | Kee KMS | QOJ KMS

- **Independent Third-party KMS** to support a managed, orchestrated, L1 Network Service

EvolutionQ KMS

- **2x KMS systems** to support inter-domain operation implementing a draft version of ETSI-GS-QKD-020

QoolNet KMS | AIT K MS



Demo Application / Service Layer

- **L1, fully managed (OTNsec)**

Up to 500Gb/s per line
Global key Orchestration
Switch to classical symmetric key encryption for redundancy

Nokia OTNsec

- **L2 encryption (MACsec)**

10Gb/s per MACsec Connection
2 different vendors

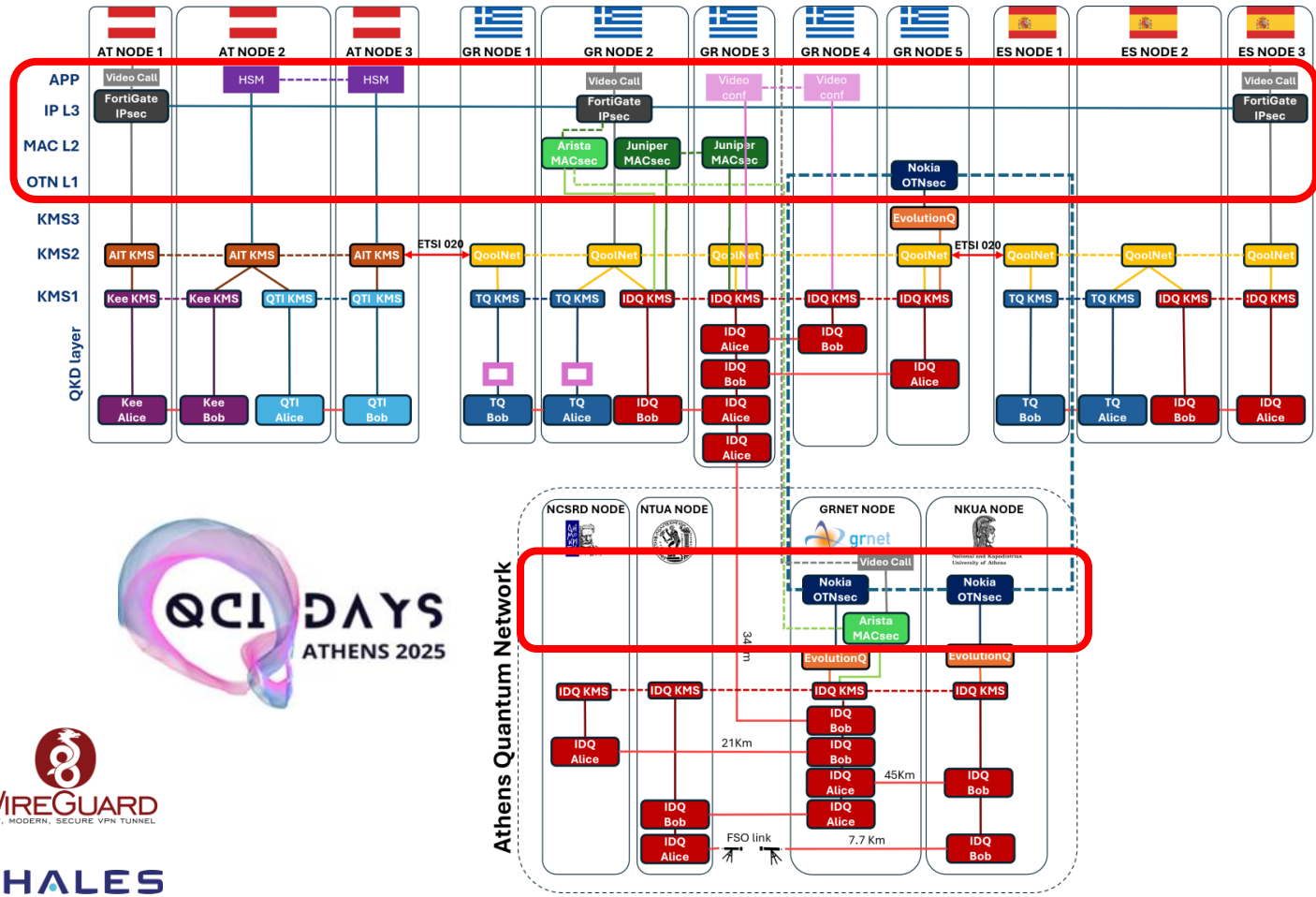
Juniper MACsec
Arista MACsec

- **L3 encryption (IPsec)**

Up to 100G per Tunnel
Over Internet

FortiGate Firewall IPsec

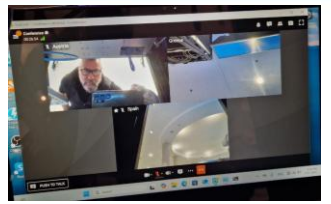
- **Application layer encryption**



First ever 4-node Quantum Secure video conference

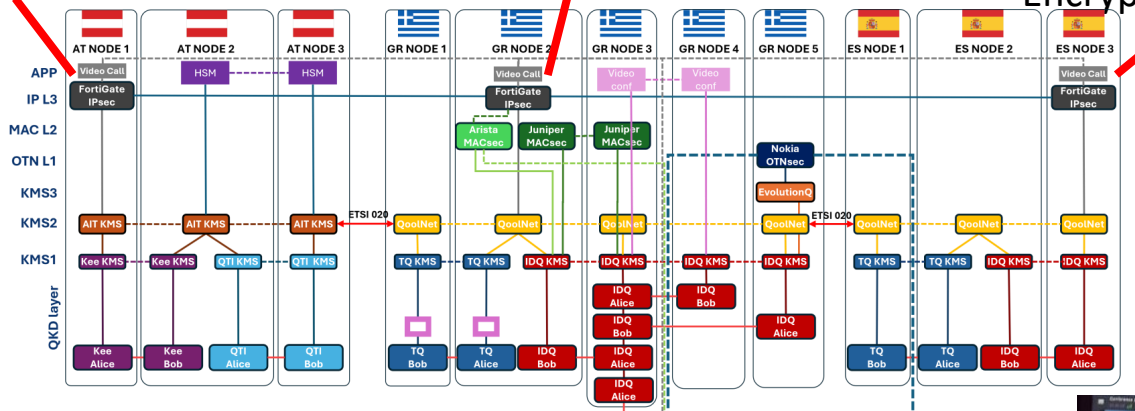
- **4-node video conference**
  - Crossing multiple nodes with other consumers in between
- **Over 3 independent networks**
  - Each with individual controls and management
- **Employing 2 different encryption schemes**
  - IPsec, MACsec
- **While running multiple other services in parallel!**
  - 3-Node 5x100G OTNsec
  - 7 Quantum encrypted applications

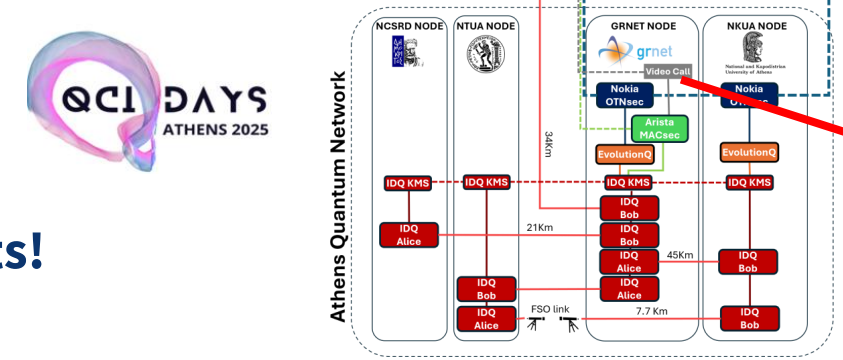
AUSTRIA
Quantum
Encrypted IP traffic



GREECE
Quantum
Encrypted IP traffic

SPAIN
Quantum
Encrypted IP traffic





NKUA
Quantum Encrypted
EtherNet

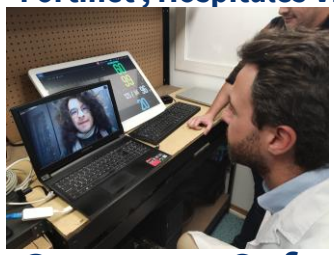
- **Closest it can get to real-world deployments!**

Intra-domain QCI-demos / Spain & Austria

Spain

- **eHealth: QKD Protected Remote Medical Diagnostic**
- **eHealth: Medical Data Protection with QKD**

  * UC in Collab. between UPM, QoolNet, LuxQuanta, Fortinet , Hospitales Vithas de Madrid & Telefónica.



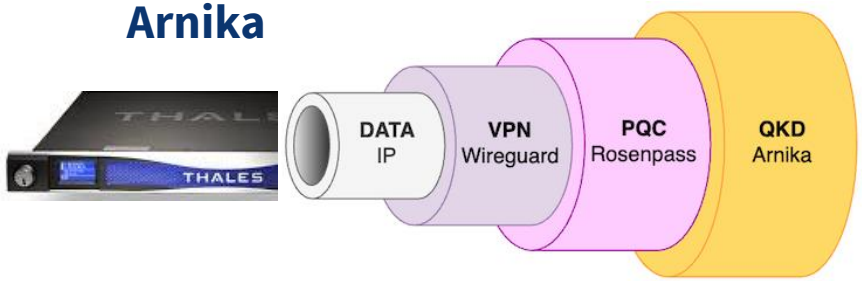
- **Quantum Safe IPsec tunnel**

- **Quantum Safe**
- **Video Conf.**

Austria

- **Chat & Video with client side E2E QKD & PQC encryption**
- **ETSI 014 group key for group calls**

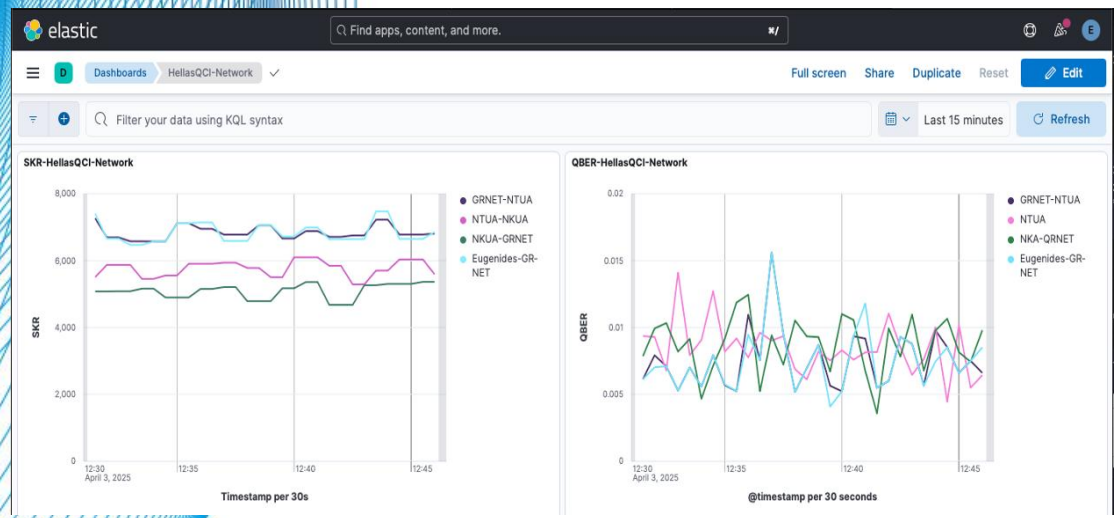
- **HSM backup over QKD & PQC Wireguard VPN channel with Arnika**



Intra-domain QCI-demos / Greece

QKD network monitoring and control software

- Monitoring tool based on Elastic developed by Space Hellas, in collaboration with NKUA.
- Centralized collection and processing of QKD network data into Elastic platform for indexing, visualization and analysis.
- Live feedback on the QKD metrics (SKR, QBER, key buffers)



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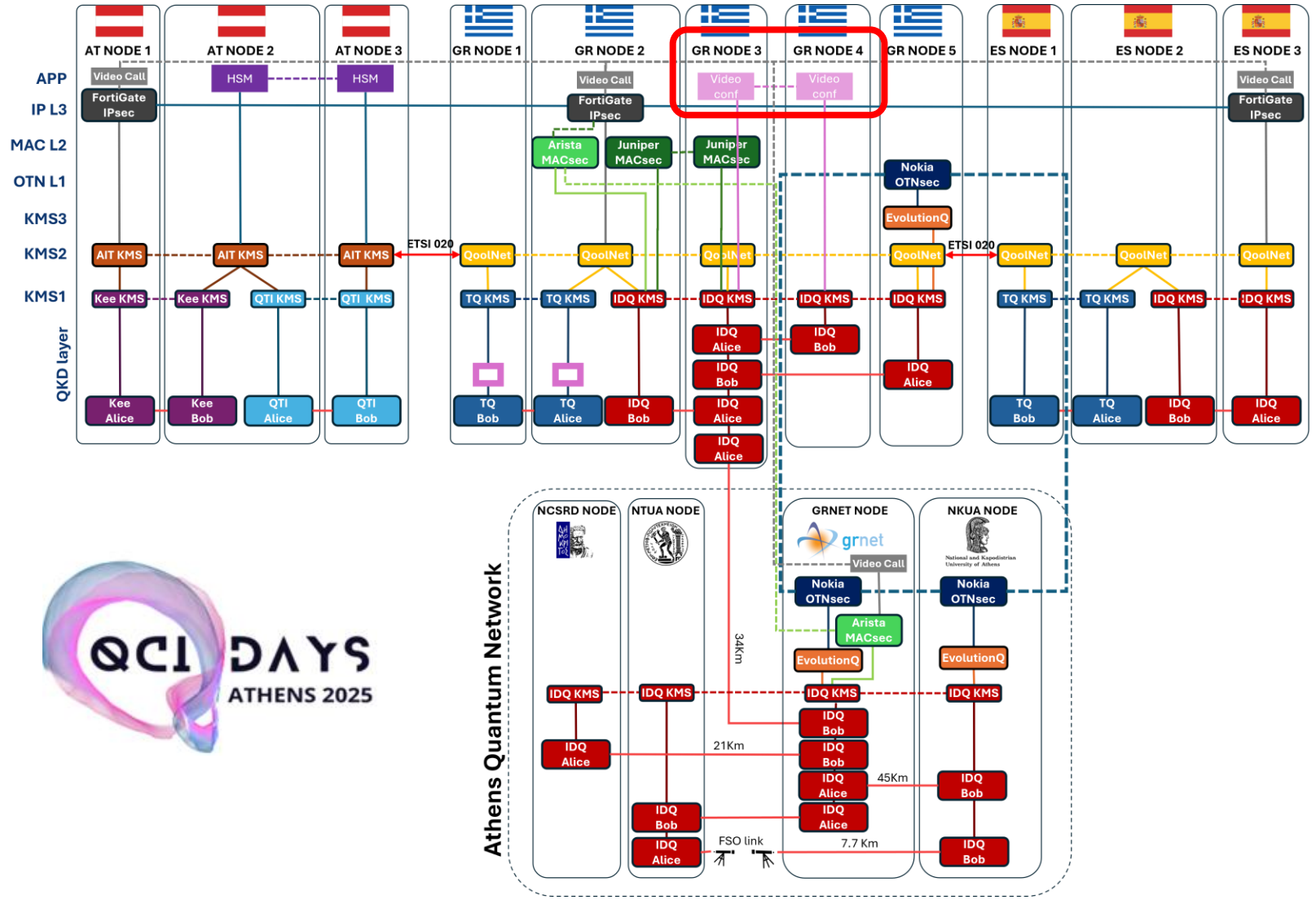
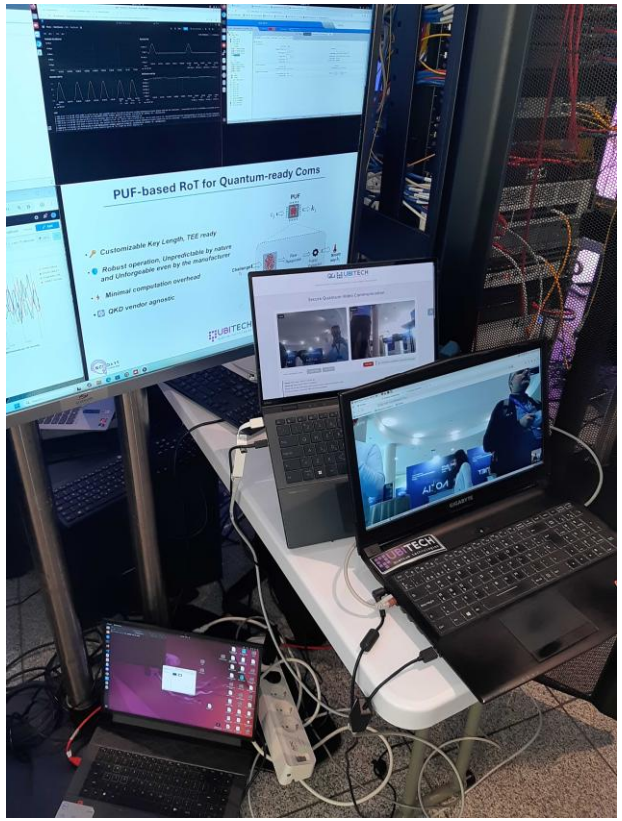
Intra-domain QCI-demos / Greece



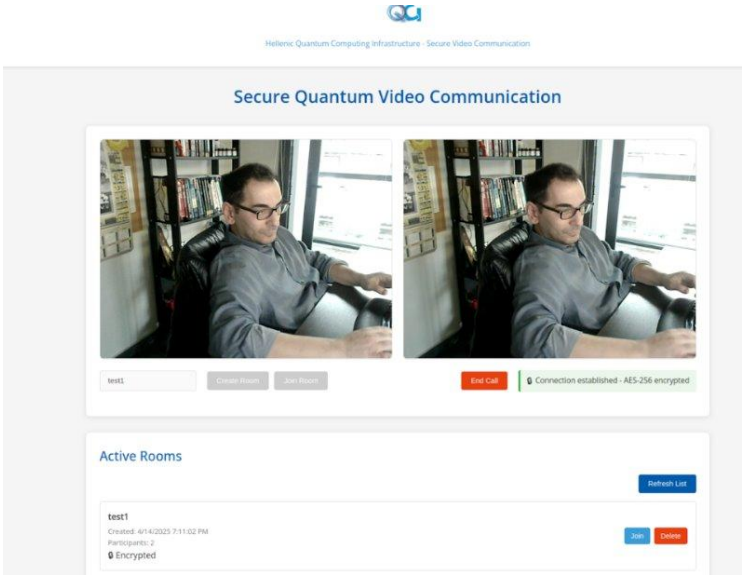
Intra-domain QCI-demos / Greece

Quantum encypted video conference software



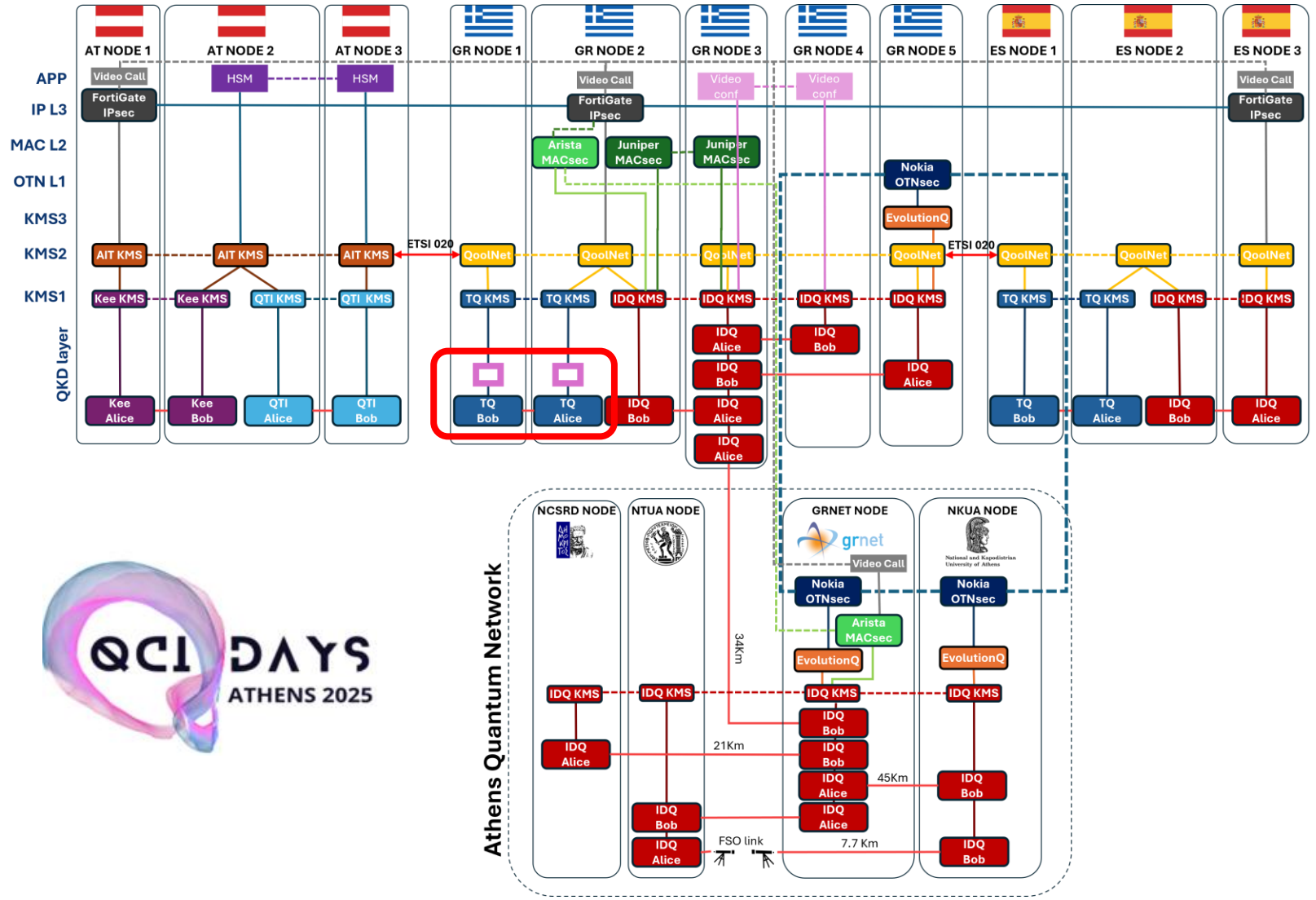
➢ **QKD-powered software app**

- Voice & Messaging: Real-time voice and text messaging secured via QKD keys in the application layer
- Each user connects through endpoints managed by the external Key Management System (KMS)
- AES-256 key generation utilizing QKD-oriented distilled keys as entropy source)
- Ensures end-to-end encryption for all communication sessions
- High-quality video communication with QKD-powered encrypted channels.



UBITECH quantum supremacy

Intra-domain QCI-demos / Greece



Intra-domain QCI-demos / Greece

Alice

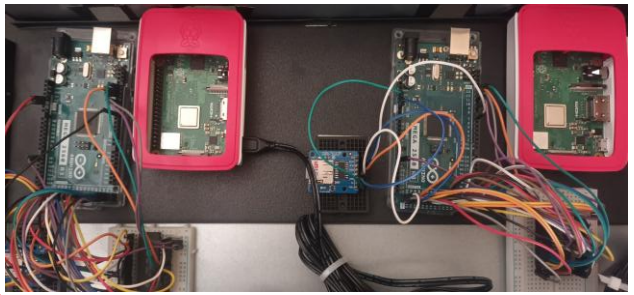
```
qkd@raspberrypi:~/hellasqci-qkd-communication-software/ServerA $ python ServerA.py
Processing entry: 452, Challenge: challenge 452, Joint Key: 3383d3b6865edc69e636c936c68382b300cdd98cbaf00388a7ecc1f682de6b19, Status: active
Verification successful!
Entry 452 marked as used. Status after update: used
qkd@raspberrypi:~/hellasqci-qkd-communication-software/ServerA $ python ServerA.py
Processing entry: 624, Challenge: challenge 624, Joint Key: 35fa3c92ae337287e749552d70fa50dc357b6726d6fcccf3186d7db829420d52, Status: active
Verification successful!
Entry 624 marked as used. Status after update: used
qkd@raspberrypi:~/hellasqci-qkd-communication-software/ServerA $ python ServerA.py
Processing entry: 961, Challenge: challenge 961, Joint Key: 2dbb0725f3d956ae462e07a7865e048afa2b91c78488c3f79f376b2e59835fe7, Status: active
Verification successful!
Entry 961 marked as used. Status after update: used
qkd@raspberrypi:~/hellasqci-qkd-communication-software/ServerA $ python ServerA.py
Processing entry: 798, Challenge: challenge 798, Joint Key: 41d893a3e53f2612504fb8aabdf2fa3cb71f389f13617eca3aa66f72e41ea612, Status: active
Verification successful!
Entry 798 marked as used. Status after update: used
qkd@raspberrypi:~/hellasqci-qkd-communication-software/ServerA $ python ServerA.py
Processing entry: 960, Challenge: challenge 960, Joint Key: 0c431e3670ffede86fe960ac6026f3aee60de9f2f3bed33d4f6e5c7f9314de29, Status: active
Verification successful!
Entry 960 marked as used. Status after update: used
qkd@raspberrypi:~/hellasqci-qkd-communication-software/ServerA $ python ServerA.py
Processing entry: 265, Challenge: challenge 265, Joint Key: 21e3db1e020be242984c4d8dda031f9811986b3610c95625a7ed67056c6be1c6, Status: active
Verification successful!
Entry 265 marked as used. Status after update: used
qkd@raspberrypi:~/hellasqci-qkd-communication-software/ServerA $ python ServerA.py
Processing entry: 965, Challenge: challenge 965, Joint Key: bcf4e1dd69117471c8a3e9dbc32eecda57f503810db6210c76368a1a1d062064, Status: active
Verification successful!
Entry 965 marked as used. Status after update: used
qkd@raspberrypi:~/hellasqci-qkd-communication-software/ServerA $ python ServerA.py
Processing entry: 319, Challenge: challenge 319, Joint Key: b2a883169a4d239765c4fc7ee334dc92b8a750bb64a5f1dc365b108399ca8ba0, Status: active
Verification successful!
```

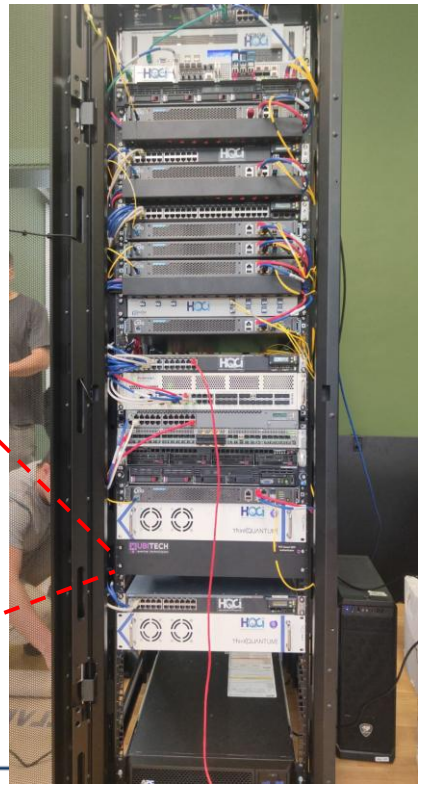
Bob

```
Press CTRL+C to quit
Received challenge: 718
192.168.1.138 - - [10/Oct/2024 09:11:42] "POST /receive_challenge HTTP/1.1" 200 -
Received challenge: 982
192.168.1.138 - - [10/Oct/2024 09:12:08] "POST /receive_challenge HTTP/1.1" 200 -
Received challenge: 125
192.168.1.138 - - [10/Oct/2024 09:12:32] "POST /receive_challenge HTTP/1.1" 200 -
Received challenge: 54
192.168.1.138 - - [10/Oct/2024 09:12:55] "POST /receive_challenge HTTP/1.1" 200 -
Received challenge: 378
192.168.1.138 - - [10/Oct/2024 09:13:38] "POST /receive_challenge HTTP/1.1" 200 -
Received challenge: 828
192.168.1.138 - - [10/Oct/2024 09:14:18] "POST /receive_challenge HTTP/1.1" 200 -
Received challenge: 540
192.168.1.138 - - [10/Oct/2024 09:15:17] "POST /receive_challenge HTTP/1.1" 200 -
Received challenge: 753
192.168.1.138 - - [10/Oct/2024 09:15:43] "POST /receive_challenge HTTP/1.1" 200 -
Received challenge: 626
192.168.1.138 - - [10/Oct/2024 09:16:06] "POST /receive_challenge HTTP/1.1" 200 -
Received challenge: 407
192.168.1.138 - - [10/Oct/2024 09:16:30] "POST /receive_challenge HTTP/1.1" 200 -
Received challenge: 749
192.168.1.138 - - [10/Oct/2024 09:16:54] "POST /receive_challenge HTTP/1.1" 200 -
Received challenge: 949
192.168.1.138 - - [10/Oct/2024 09:17:19] "POST /receive_challenge HTTP/1.1" 200 -
Received challenge: 402
192.168.1.138 - - [10/Oct/2024 09:17:42] "POST /receive_challenge HTTP/1.1" 200 -
Received challenge: 979
192.168.1.138 - - [10/Oct/2024 09:18:06] "POST /receive_challenge HTTP/1.1" 200 -
Received challenge: 662
192.168.1.138 - - [10/Oct/2024 09:18:30] "POST /receive_challenge HTTP/1.1" 200 -
Received challenge: 326
192.168.1.138 - - [10/Oct/2024 09:18:53] "POST /receive_challenge HTTP/1.1" 200 -
Received challenge: 144
192.168.1.138 - - [10/Oct/2024 09:19:18] "POST /receive_challe
Received challenge: 304
192.168.1.138 - - [10/Oct/2024 09:19:41] "POST /receive_challe
Received challenge: 44
192.168.1.138 - - [10/Oct/2024 09:20:08] "POST /receive_challe
```

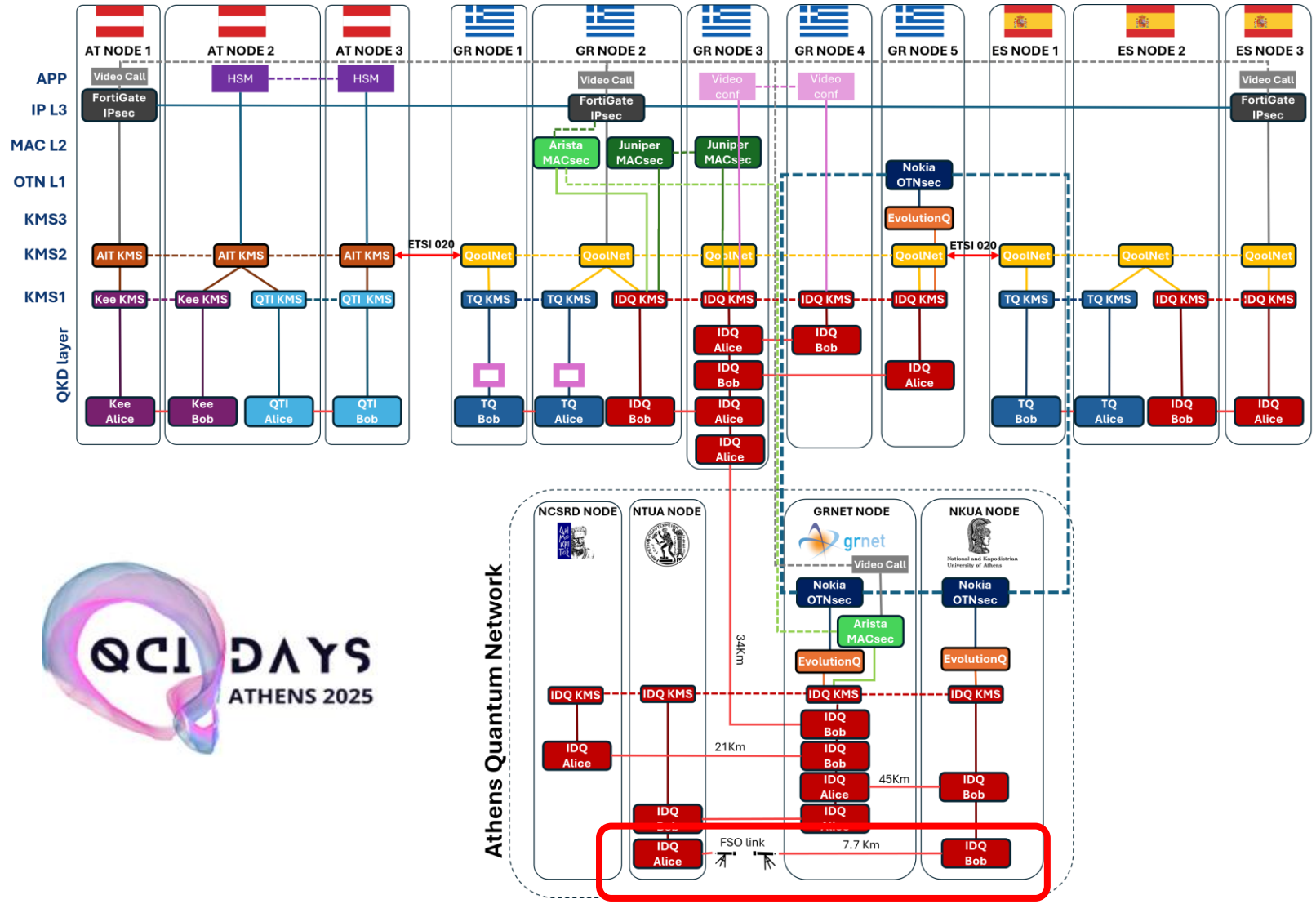
Hybrid PQC/PUF Authentication

- Plug and play operation with commercial QKD
- Integrated with ThinkQuantum QKD system



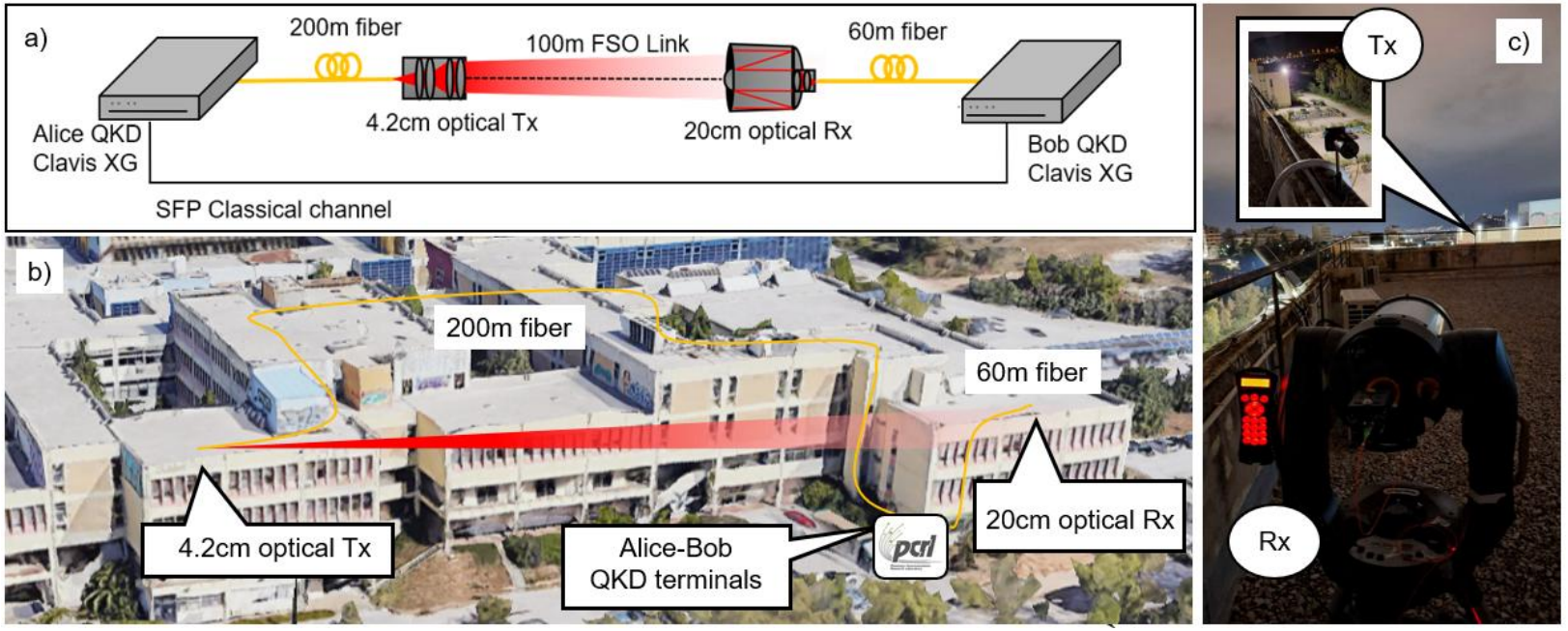


Intra-domain QCI-demos / Greece



Intra-domain QCI-demos / Greece

NKUA-NTUA Fiber-Wireless Fiber QKD link



Thank you!

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HellasQCI - Quantum Communication Infrastructure for Greece

HellasQCI.eu

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EuroQCI

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