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Quantum-Native Architectural Tenets and Philosophy for the Quantum Internet

Update on draft-cacciapuoti-qirg-quantum-native-architecture-01

From entanglement as a resource to quantum-native control abstractions

IETF 126 VIENNA 2026

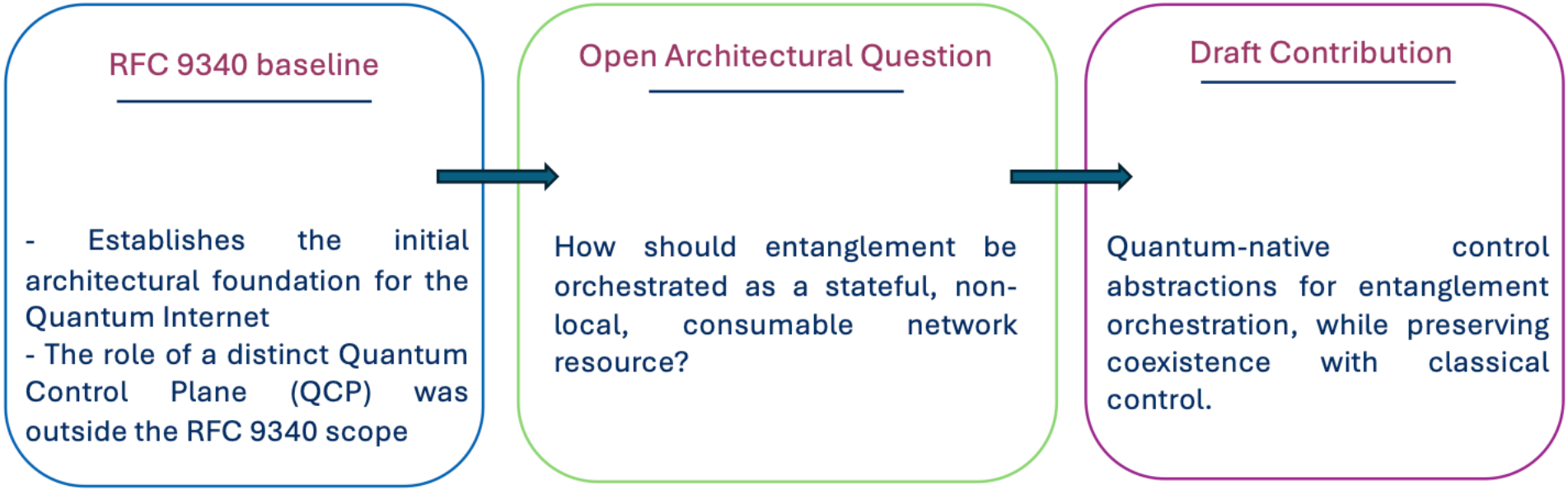
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qnattynet.quantuminternet.it

QNattyNet
quantum-native communication network

QQuantum Internet.it
wiring the weirdness

From RFC 9340 to Quantum-Native Control Considerations

How should the Quantum Internet orchestrate entanglement as a network resource?



Version -01: what changed

The architectural core is preserved; the agnosticism story is strengthened

Preserved from -00

QDP/QCP separation · EDC · Quantum Addressing · quantum packet abstraction · Generalized Quantum Forwarding · entanglement-aware control.

Editorial change

Authorship expanded with A. Abane and J. Chung.

Routing-model & Repeater-generation agnosticism

Avoids binding the framework to a single routing model.

Treats repeaters primarily as network functions, rather than tying the architecture to one generation.

Multi-domain routing and forwarding considerations

Introduces intra-domain and inter-domain considerations, including coordination across domains.

Clarified abstractions

Strengthens QA as a control abstraction and GQF as a forwarding/execution abstraction.

Architectural scope of the draft

A structured view of the issues addressed

1 · Resource

Entanglement is non-local, volatile, consumable, and stateful.

2 · Architecture

The network requires explicit separation between operations and entanglement orchestration.

3 · Quantum-Native Control

Quantum Addressing is the control-plane abstraction for reasoning over entanglement relations beyond physical connectivity.

4 · Generalized Forwarding

GQF captures how control decisions are executed through local entanglement manipulation.

5 · Agnosticism

The framework must support multiple routing models, repeater generations, and administrative domains.

The draft is architectural: it proposes abstractions and terminology for discussion; it does not prescribe one implementation path.

Entanglement Changes The Architecture

The network cannot be blind to the entanglement-resource state



Non-local

Local operations affect shared correlations among remote nodes



Volatile

Entanglement decoheres over time and is depleted upon use



Stateful

Fidelity, coherence budget, ownership, and availability must remain visible to control



Entanglement proximity

Quantum connectivity differs from physical connectivity

The network must reason over entanglement dynamics, not only over physical graphs.

Entanglement Changes The Architecture

The network cannot be blind to the entanglement-resource state

Persistent state awareness

Track fidelity, coherence budget, ownership and identifiers across time and nodes

Coordinated in-network operations

Generate, swap, purify and consume entanglement without losing resource consistency

Explicit orchestration mechanisms are required to manage entanglement resources.



State visibility across the whole life-cycle

Operations coordinated across remote nodes

Architectural Consequences

The network cannot be blind to the entanglement-resource state



One resource

From entanglement as a resource to quantum-native control

1 SEPARATE

Operations from orchestration

QDP executes quantum operations.
QCP orchestrates entanglement resources.

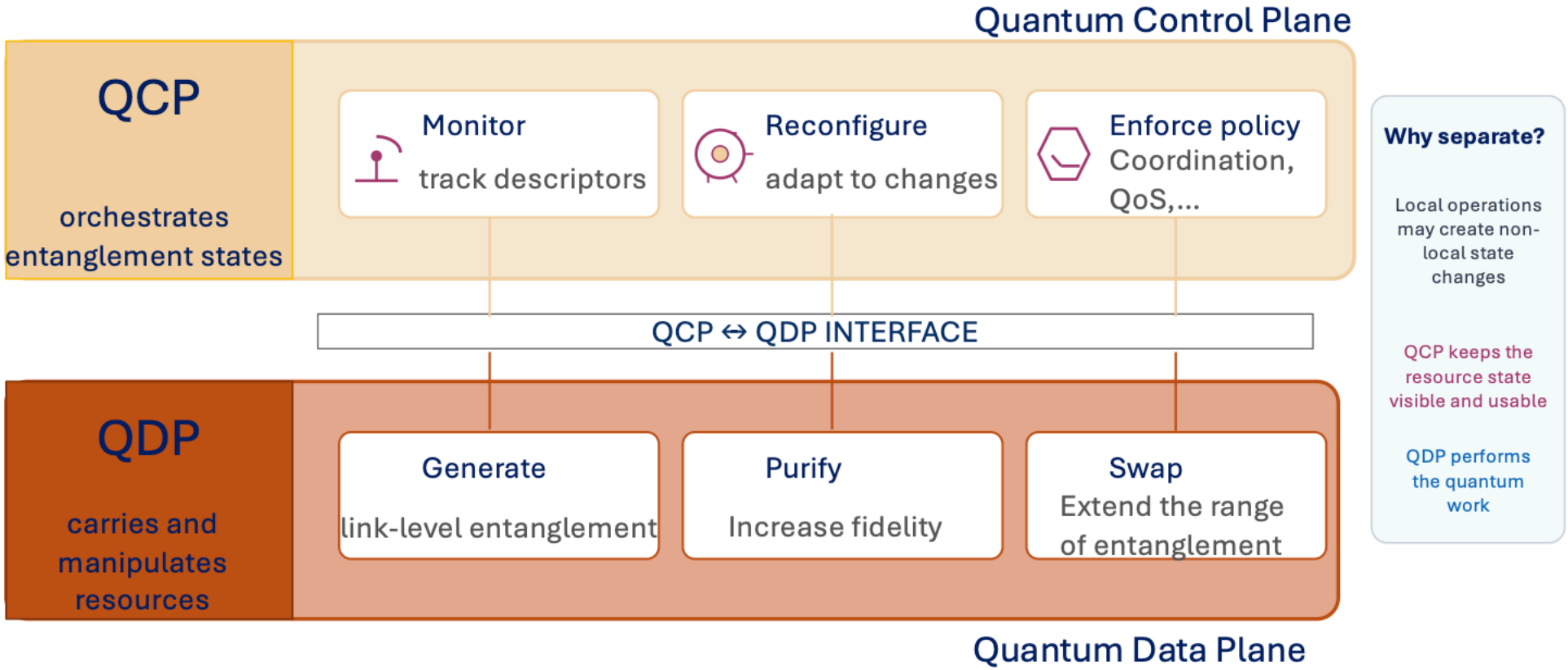
2 Scale Quantumness into the control plane

Topology-driven control abstractions are necessary but not sufficient alone

QA is the quantum-native control abstraction. GQF provides the corresponding forwarding abstraction for local manipulation of entanglement resources under control guidance

Core Model: two functional planes

Explicit and functional plane decoupling, not a claim that classical control plane disappears

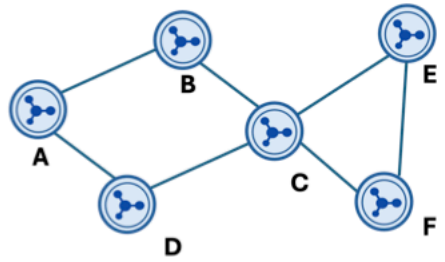


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Why Quantum-Native Control Abstractions?

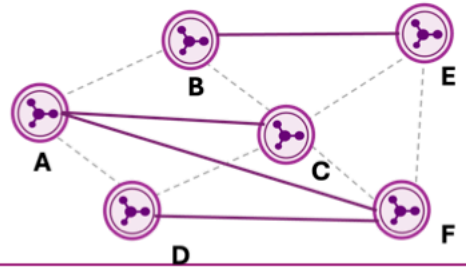
Classical control is necessary, but topology-driven control abstractions alone may be insufficient

Physical Graph
Relatively Stable



≠

Entanglement graph
Resource State does not follow topology



Classical control
Grounded in Locality and Topology-driven Abstractions



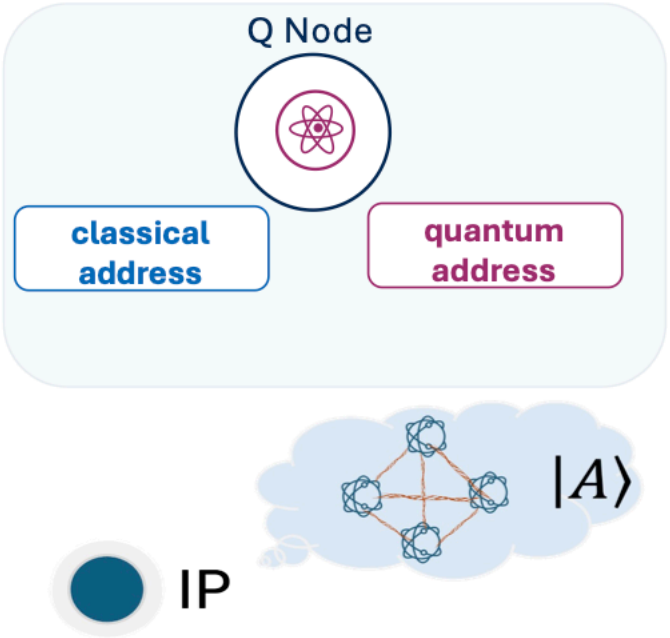
Entanglement Dynamics

→

Scalability Bottleneck:
State tracking, Response,
and Coordination

Quantum Addressing as a Control Abstraction

Each node has two identifiers with different roles: classical and quantum



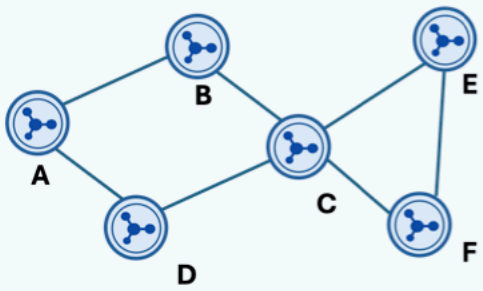
- QCP operates on node sets
  via quantum superposition
- compact routing table
  avoid topological-driven only identifiers
- QCP makes entanglement-aware decisions
  aligned with resource relations not captured by physical topology alone

The draft treats quantum addressing as a control abstraction and not as a replacement of classical addressing

Physical Graph vs Entanglement Graph

Control must reason not only about physical graphs but also about entanglement graphs

Classical view
Physical graph

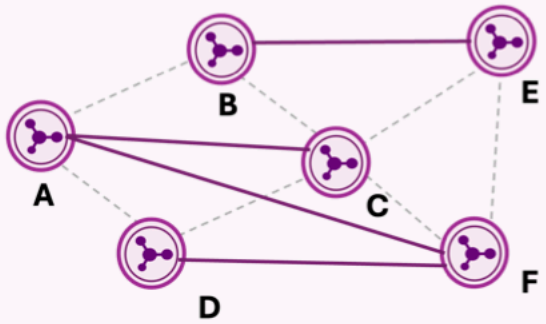


- Determines where elementary link-level entanglement generation is feasible.
- Relatively stable compared with entanglement availability.

Dual-addressing framework

classical address	+	quantum address
IP-like		entanglement relations
Classical Routing Table		Quantum Routing Table

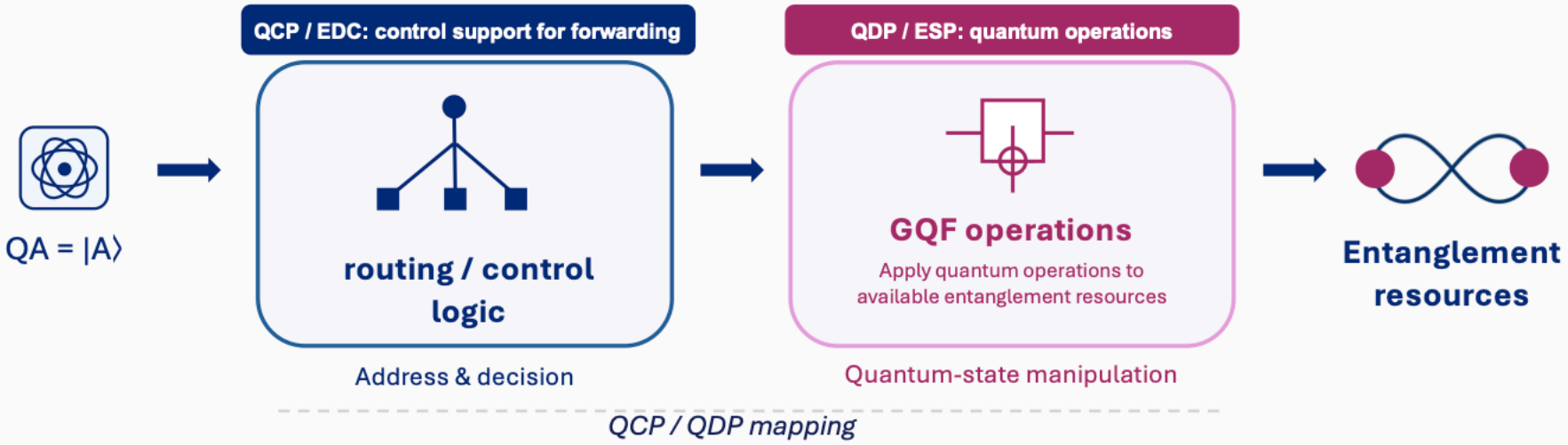
Entanglement view
Entanglement graph



Represents currently available, exploitable entanglement relations

Generalized Quantum Forwarding (GQF)

Forwarding decisions may require the capability to operate directly on quantum identifiers



Generalized Quantum Forwarding

- Not classical match-and-forward logic: the term “forwarding” is used analogically, not literally
- Local manipulation of entanglement resources under routing/control guidance.
- Supports establishment, extension, or transformation of entanglement toward a communication objective.

Agnosticism Considerations for Quantum-Native Networking

The framework is designed to avoid premature binding to one realization

Routing model agnosticism

The QCP can accommodate different routing models:

- physical-proximity view
- entanglement-proximity view

proactive or reactive entanglement generation

WHAT MAY CHANGE

Repeater generation agnosticism

The repeater is treated primarily as a network function:

1st gen — 2nd gen — 3rd gen

QDP mechanisms may evolve

from physical primitives to logical entanglement resources

PRESERVED ELEMENTS

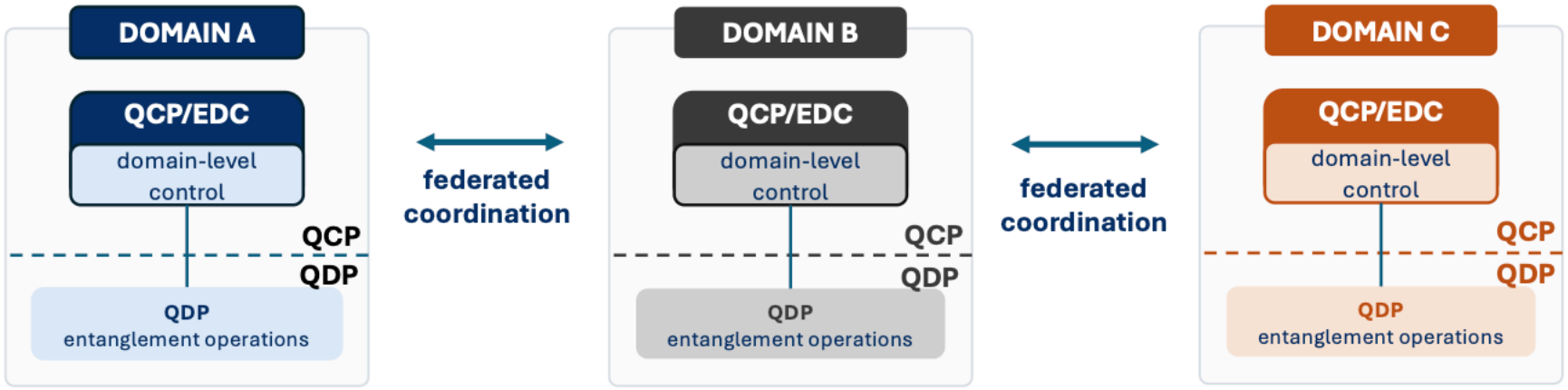
Quantum-native architectural abstractions: QCP | QDP | QA | GQF

QDP / QCP separation – EDC orchestration – Quantum Addressing – Generalized Quantum Forwarding

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Multi-domain view

Federation provides a scaling model



WITHIN DOMAINS

Each domain preserves local autonomy:

→ local state management

→ local routing & policies

ACROSS DOMAINS

Domains may exchange:

→ physical connectivity

→ entanglement reachability

→ policies, metrics

Proposed Quantum-Native Architectural Principles

Compact summary

Entanglement as resource	Ebits serve as fundamental network units, carrying quantum correlations across nodes.
Explicit Plane Decoupling	QDP and QCP separate operations from orchestration.
Quantum Addressing	Control logic uses quantum identifiers.
Hybrid Control Coexistence	Quantum-native control complements classical control.
GQF	Local entanglement manipulation under control guidance.
Deployment Agnosticism	Routing models, repeater generations, and domains remain open.

Mailing-list feedback and the -02 agenda

Plane boundaries

Clarify how the two-plane functional model relates to other QIRG plane/strata models

Control model boundaries

Clarify whether QDP includes supporting classical signaling and how QCP relates to classical control.

Quantum packet / GQF

Define the abstraction precisely and avoid misleading classical interpretations.

Graph distinction

Make the physical graph and entanglement graph distinction explicit.

Core message

The comments received on the mailing list identify precision work for -02: definitions, boundaries, terminology, and safe wording. The architectural core remains unchanged.

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Next steps toward version -02

Concrete edits planned after the QIRG discussion

1 · Tighten definitions

Define orchestration, quantum packet, GQF, QDP, QCP, and EDC more explicitly.

2 · Clarify control boundaries

State how classical signaling supports QDP operations and how hybrid control fits the QCP view.

3 · Improve wording safety

Remove or qualify expressions that could suggest misleading interpretations for non-specialists.

4 · Terminology Alignment

Ask QIRG whether a broader terminology-mapping effort is useful and feasible.

5 · Strengthen multi-domain text

Clarify networking vs internetworking and the information exchanged across domains.

6 · Add references

Include relevant complementary work, including quantum control perspectives and classical-network core complexity discussions.

Version -02 objective

Move from a conceptually clear architectural proposal to a terminology-safe, QIRG-readable, and discussion-ready draft.

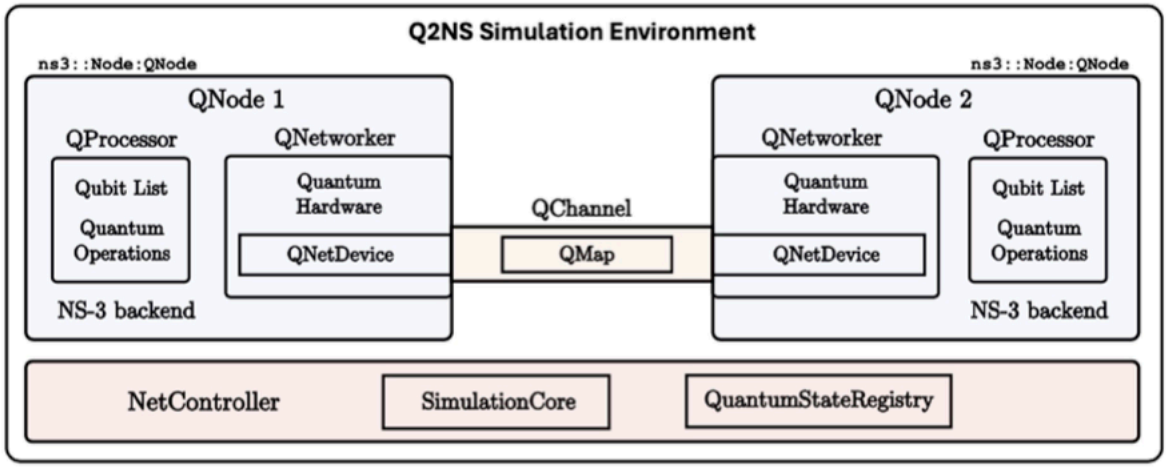
Q2NS: Quantum-Native Validation Environment

The tenets matter only if they remain operational at scale

Needing a framework where

- quantum state dynamics
- control logic
- classical dynamics
- protocol-level behavior

are observable together



Separation between network control and in-network operations becomes operational

Thank you

Questions and comments

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draft-cacciapuoti-qirg-quantum-native-architecture-01

Status | Email expansions | History

Versions:

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