

16TH ITU ACADEMIC CONFERENCE

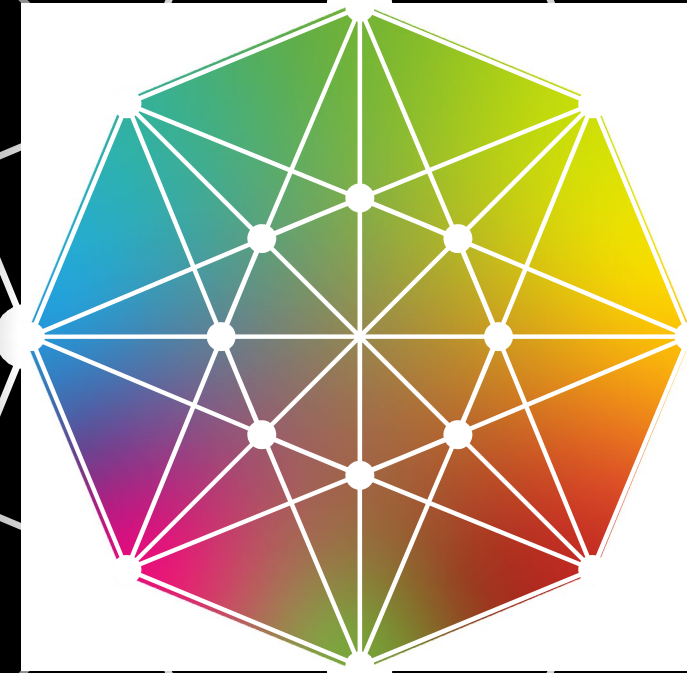
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An Innovation Ecosystem Ethics Approach for Quantum Safe Transitions

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Paper Session 7 – Infrastructure, sustainability, and emerging tech ecosystems





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Quantum Safe Transition (QST): From Technical Migration to Ecosystem Redesign

QST is dominantly framed as a technical migration. We argue it is a socio-technical-ecological reconfiguration.

DOMINANT FRAMING

Technical Governance

- Post-Quantum Cryptography (PQC)
- Quantum Key Distribution (QKD)
- Cryptographic agility
- Technical migration roadmaps

→ **Under-theorized:**
the socio-technical, ethical, and
ecosystem dimensions of QST

OUR ARGUMENT

QST not just Technical Migration

Quantum-induced vulnerability is:

- Collective
- Intertemporal
- Non-linear
- Value-laden
- Transboundary

→ **Ecosystem governance is required**

From Technical Governance to Ecosystem Governance

TECHNICAL GOVERNANCE

(Current Focus)

Which cryptographic solution is most secure and efficient?

Technical experts e.g Cryptographers, engineers, vendors, and standards experts.

Algorithm vulnerabilities, interoperability failures, implementation challenges, and system performance.

Quantum-safe cryptographic systems.

Key
Question

Stakeholders

Primary Risks
Considered

Outcome

ECOSYSTEM GOVERNANCE

(Our Argument)

Who is responsible, for what, according to which values, and for whose benefit?

Governments, industry, academia, civil society, regulators, infrastructure operators, standards bodies, and end users.

Quantum divides, accountability gaps, value conflicts, unequal participation, dependency, ethical risks, and governance asymmetries.

A trusted quantum-safe ecosystem characterized by security, accountability, inclusion, resilience, interoperability, legitimacy, and trust.

Key Ethical Challenges for Quantum-Safe Transitions



Temporal uncertainty and multidimensional insecurities
Delayed migration by a single actor can undermine the security and resilience of interconnected and interdependent digital systems



Multi-stakeholder value conflict

- Privacy
- Safety
- Surveillance
- National security
- Strategic autonomy
- International cooperation
- Digital commons
- Human rights



Future-oriented accountability

Who is responsible when today's design choices create harms decades later?

Approach : QST as Socio-Technical Reconfiguration

CONTRIBUTION

- ✔ Demonstrate that QST is a **Digital Innovation Ecosystem** transformation.
- ✔ Connect **ethical considerations** to practical technical ecosystem dynamics.
- ✔ Develop a novel analytical **Integrated Framework** for QST governance.

CORE ARGUMENT

QST constitutes a broader socio-technical-ecological reconfiguration with significant **ethical, legal, societal, and policy implications (ELSPI)**, thus interventions should be approached as a whole-of-ecosystem redesign challenge.

INNOVATION ECOSYSTEM ETHICS (Normative Foundation)

ANTICIPATION

Foresight, preparation and proactive action

REFLEXIVITY

Continuous reflection, critical assessment and learning

INCLUSION

Inclusive participation and consideration of diverse perspectives

RESPONSIVENESS

Adaptive governance and responsiveness to change

INNOVATION ECOSYSTEM CONTEXT

Institutions

Infrastructure

Stakeholders

Knowledge

Investments

Markets

Values & Norms

Policy & Regulation

Standards

COGNITIVE / DECISIONAL LAYER (Governance, Standards, Policy)

Governance Focus: Governance structures, standard-setting, policy development, migration asquencing, resource allocation

Typical Actors: Governments, Regulators, ITU, ETSI, ISO/IEC, NIST, Policy Makers, Civil Society

Key Ethical Risks: Agenda asymmetry, exclusion from governance, unequal standards participation, quantum divide, strategic dependencies

INFORMATIONAL LAYER (Protocols, Data Flows, Cryptography)

Governance Focus: Encryption protocols, data flows, cryptographic agility, key management, data lifecycle protection, interoperability

Typical Actors: Standards Bodies, Cybersecurity Agencies, Software Vendors, Crypto Providers, Certification Authorities

Key Ethical Risks: Harvest-now-decrypt-later (HNDL) exposure, fragmented migration pathways, interoperability failures, data integrity risks

PHYSICAL LAYER (Infrastructure, Hardware, PKI, QKD)

Governance Focus: Infrastructure migration, hardware deployment, PKI modernization, QKD network deployment, physical asset management

Typical Actors: Telecom Operators, Cloud Providers, Hardware Vendors, Network Operators, Infrastructure Providers

Key Ethical Risks: Uneven deployment, vendor lock-in, infrastructural exclusion, concentration of capabilities, vulnerabilities in critical infrastructure

CROSS-CUTTING PRINCIPLES

Transparency

Accountability

Security & Resilience

Fairness & Equity

Sustainability

Global Solidarity

ADAPTIVE GOVERNANCE: FEEDBACK AND LEARNING LOOPS

Monitor

Continuous monitoring of technological, governance, and ethical developments

Assess

Assess risks, impacts, and readiness across layers

Adapt

Adjust strategies, policies, and standards

Coordinate

Coordinate across stakeholders, sectors, and regions

Sustain

Sustainable and resilient outcomes over time

COGNITIVE / DECISIONAL LAYER

Governance, standards & policy

Risks: agenda asymmetry, exclusion, quantum divide..

INFORMATIONAL LAYER

Protocols, data flows, cryptography

Risks: Harvest-now-decrypt-later, fragmented migration pathways..

PHYSICAL LAYER

Infrastructure, hardware, PKI, QKD

Risks: Uneven deployment, vendor lock-in, infrastructural exclusion, concentration of capabilities..



A three-dimensional matrix to further operationalise the Integrated Framework

A rank 2 tensor is used to visualize the interactions between the three domains or layers of the information environment and the ELSPI dimensions at each unit of analysis

ELSPI
×
IE layers
×
unit of analysis
⇒
60 interconnected nodes

AXIS	DIMENSION	VALUES			
X	ELSPI	0 Ethical	1 Legal	2 Societal	3 Policy
Y	Information Environment	0 Physical	1 Informational	2 Cognitive/Decisional	
Z	Unit of analysis	0 Individual	1 Organizational	2 National	3 Regional
		4 Global			
Total Nodes 4x3x5 = 60					

Quantum-Safe Transitions are ecosystem-wide governance transformations rather than discrete technical upgrades

QST require coordinated action across infrastructures, institutions, standards, stakeholders, and governance systems

- **Technical governance** delivers the "how" of quantum-safe migration
- **Innovation ecosystem governance** addresses the "why", "who" , and "according to whose values" of quantum-safe transitions.

Thank you!

