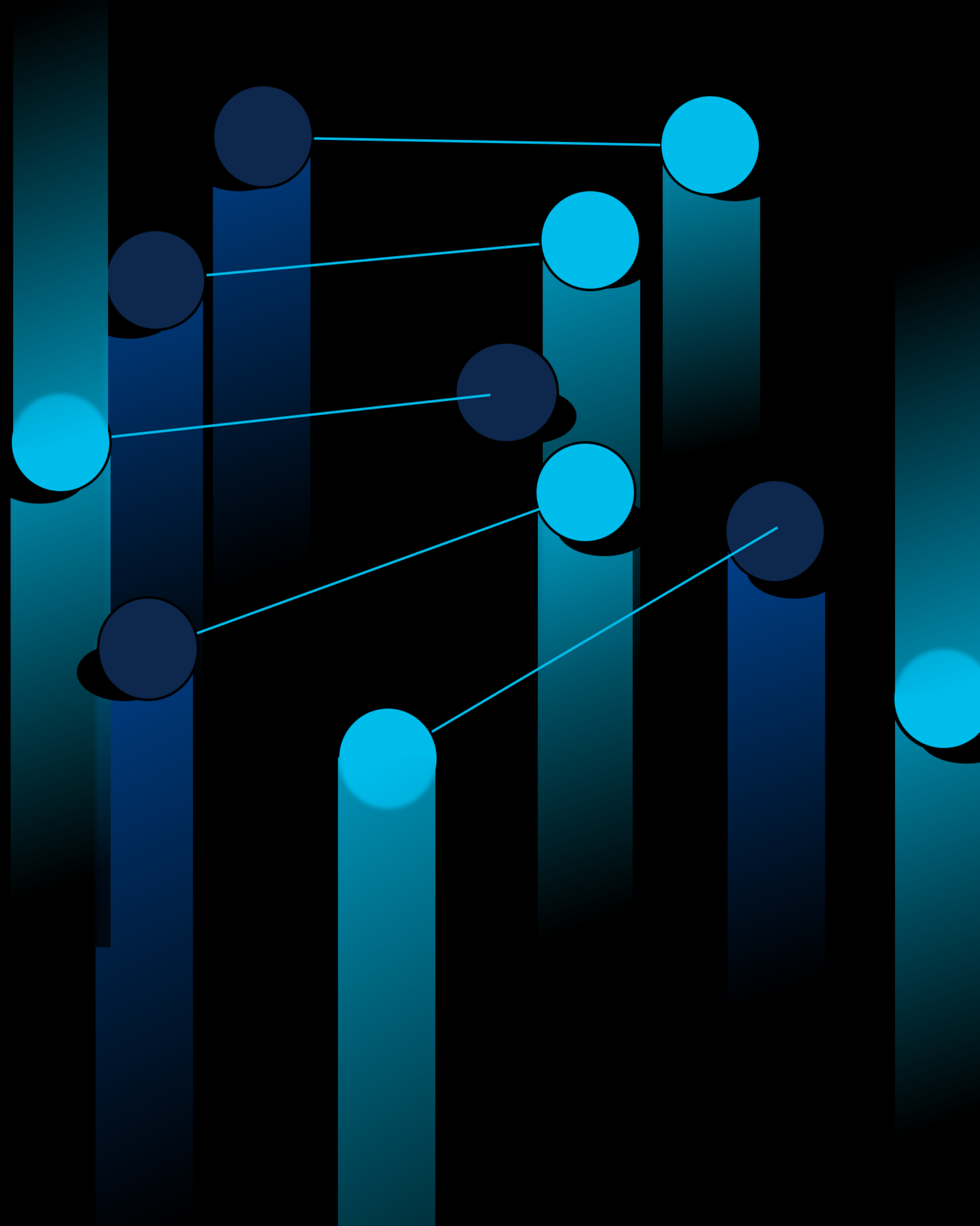
Cisco Quantum Labs



Utilizing Cisco's Quantum Networking technology in support of classical applications

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Summary

Cisco's advancements in developing a unified quantum networking software stack are designed to deliver entanglement connectivity that enhances classical applications and enables entirely new ones with performance beyond today's networks. This stack establishes the foundation for classical quantum integration and the emergence of novel quantum-enabled applications. We are announcing this software stack together with a demonstration highlighting two applications enhanced by quantum entanglement: Quantum Sync and Quantum Alert.

Quantum entanglement for classical applications

Entanglement is a fundamental principle of quantum mechanics that enables quantum information communication and transport. In quantum mechanics, when two particles become entangled, their states become intrinsically linked, maintaining correlation irrespective of the distance separating them or the absence of physical connection.

Key features of entangled particles include:

> **Shared state:** Entangled particles form a joint quantum state, meaning neither particle can be fully described independently.

> **Quantum correlations:** Measuring one particle instantly determines the state of the other, even across vast distances. This does not imply faster-than-light communication, but rather nonlocal correlations beyond what classical physics can explain.

> **No cloning:** Quantum state of entangled particles cannot be copied, and once measured, the lose their quantum properties.

With these unique features, quantum entanglement can enhance classical applications and enable entirely new ones. Potential applications include time synchronization, secure communications, position verification, and distributed decision coordination.

Cisco is advancing the development of hardware and software technologies to realize a Quantum Networking infrastructure capable of delivering entanglement connectivity. This leverages the unique properties of quantum entanglement to both enhance existing classical applications and enable entirely new classes of applications (e.g., distributed decision coordination).

We are actively developing the technologies necessary for the Quantum Network through high-rate, high-fidelity entanglement distribution over a scalable, multi-tenant, multi-user architecture. The network is dynamically switched, allowing on-demand delivery of entanglement between any two endpoints, thereby ensuring flexibility, scalability, and broad applicability across diverse use cases.

The Quantum Network Entanglement Chip was recently released operating at telecom wavelengths with an ultra-high pair generation rate (>200M entangled pairs/second) and exceptional fidelity (~99%). We have invested in a startup building a dual-frequency entanglement source capable of generating entangled pairs at both telecom and near-infrared (NIR) wavelengths, paving the way for linking heterogeneous quantum computers into a unified Quantum Network.

In parallel, we are aggressively developing a novel quantum switch that will significantly accelerate Cisco's capability to realize all-to-all and on-demand connectivity in a Quantum Network. We are also working on the development of quantum memory with our technology partners, with a goal to realize a robust memory that supports heralded storage and retrieval of quantum-entangled photons. This will enable efficient synchronization and distribution of entanglement across large-scale quantum networks.

As hardware advances rapidly, we recognize that building a Quantum Network also requires hardware-software co-design. A key element of this effort is the development of a unified quantum networking software stack that hosts the necessary intelligence and protocols to provide entanglement distribution and quantum connectivity. It abstracts the complexity of the physical layer and orchestrates entanglement resources across heterogeneous hardware platforms. This enables applications to request, schedule, and utilize entanglement connectivity to ensure quantum computers, sensors, and other devices can interconnect reliably and efficiently. The software stack is comprised of common network protocols and intelligence including: entanglement distribution, entanglement swapping, teleportation, and quantum measurement.

By leveraging this unified software stack together with our entanglement-enabled network hardware, we are demonstrating two pilot use cases: Quantum Sync and Quantum Alert.

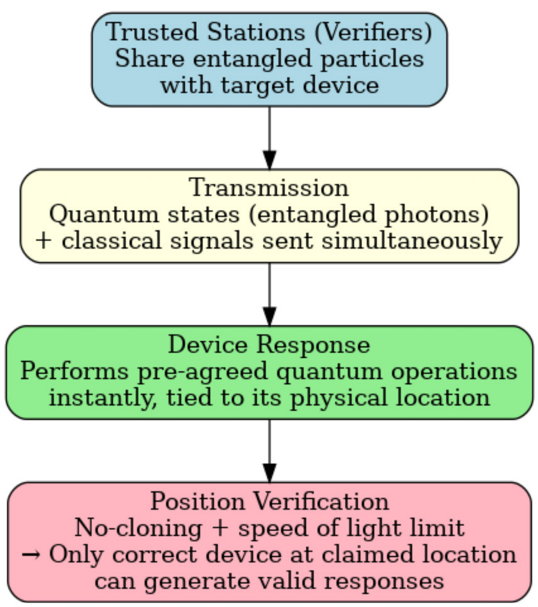

Fig 1. Quantum entanglement enhanced position verification.

Quantum Alert: Eavesdropper protection

Modern telecom networks rely on fiber for high-capacity data transport. However, these fibers are vulnerable to physical tapping, spoofing, or tampering through malicious intervention. Conventional security measures such as encryption or classical intrusion detection sensors may fail to detect subtle or sophisticated physical attacks.

An entangled quantum system (e.g., entangled photons) is inherently sensitive to any attempt to eavesdrop, spoof, or tamper. Such attempts will disturb and break the entanglement. This collapse can be detected, serving as a tamper-proof alert signal. An entanglement-based

Quantum Alert is thus a powerful security mechanism that leverages entanglement to detect unauthorized access, physical tampering, or intrusion in real time.
Quantum Alert is an eavesdropper-proof security application prototype from Cisco Quantum Labs. It uses quantum physics to detect eavesdroppers by changing the quantum properties upon access, both immediately alerting and eliminating the breach.

The following shows and entanglement-based Quantum Alert workflow:

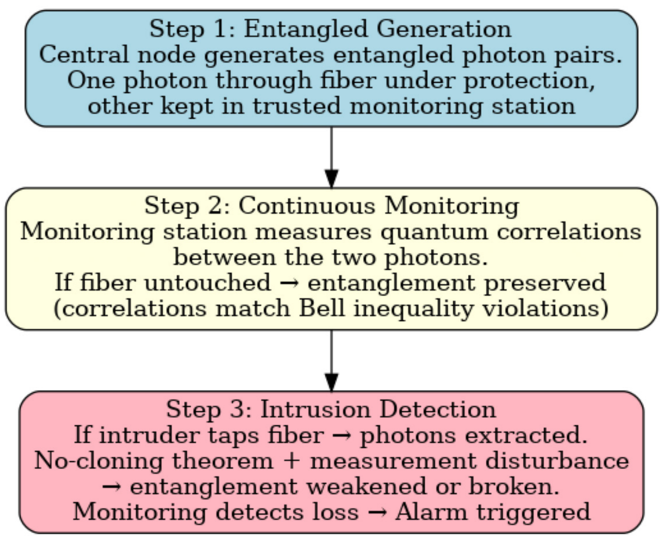

Fig 2. Quantum Alert entanglement-based eavesdropper protection.

Quantum Alert offers key advantages over classical fiber monitoring: attackers cannot tap without disrupting entanglement (unlike power-level or scattering based monitoring), any intrusion instantly causes a detectable change in Quantum state, and—with careful design—the system can be integrated into existing telecom fiber.

Potential industry use cases for Quantum Alert include protecting communication links and fiber infrastructure in financial services, telecom operator, defense and aerospace, and critical utility infrastructure.

Quantum Sync: A decision coordination application

Many applications require distributed agents (humans, computers, or robots) to make correlated decisions without the ability to communicate directly in real time. A prominent example is high frequency trading in the financial sector.

Classical communication approaches rely on signaling (messages, pings, votes), which introduces often intolerable delays for these applications, even over optical fiber. This can also introduce security vulnerabilities such as interception or spoofing.

Quantum entanglement, by contrast, provides a shared nonlocal resource that enables correlated outcomes across all parties, regardless of distance or the absence of classical communication. With entanglement, it is possible to establish a system that distributes shared randomness or shared decision variables, which can be securely accessed at multiple remote locations.

Quantum Sync developed by Cisco Quantum Labs, is a tool that enables development of decision coordination applications based on quantum entanglement.

The following workflow shows how Quantum Sync communicates decisions:

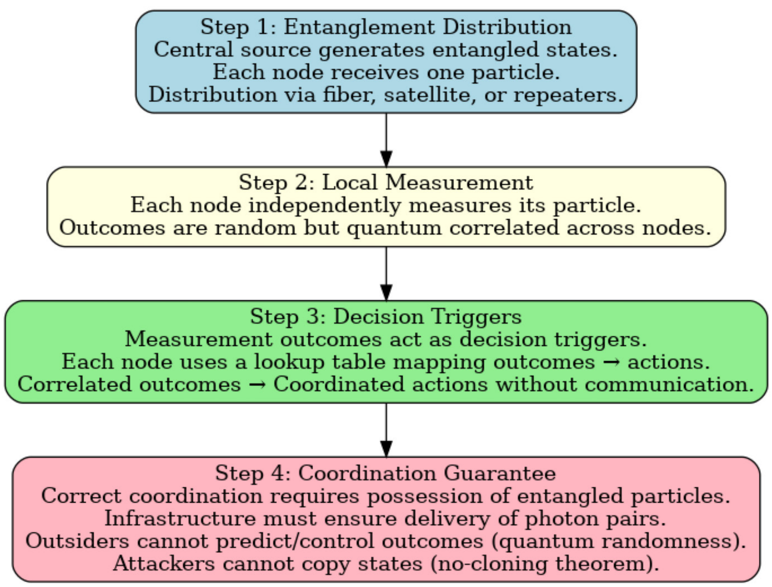

Fig 3. Quantum Sync entanglement-based decision coordination.

The advantages of entanglement-based coordination over classical coordination are twofold: reduced delay and enhanced security.

Classical coordination relies on exchanging messages (e.g., voting, consensus protocols, or time-stamped signaling). Even with optical fiber, these exchanges are limited by fiber propagation delay (~5 μs per km) and often require multiple communication rounds, adding significant latency.

In contrast, Quantum Sync eliminates the need for messaging. The "decision variable" is shared in advance via entangled particles. At decision time, no signaling is required—each node simply measures its entangled particle. The outcomes are correlated through nonlocal correlations. This results in no propagation delay at decision time and no multi-round consensus steps are required.

With entanglement, outcomes are generated on demand at the moment of measurement. The randomness does not exist beforehand (quantum indeterminacy), and correlations cannot be simulated classically without communication (as proven by Bell's theorem). This ensures that each decision cycle provides fresh, secure, and un-spoofable correlations, resistant to interception or prediction.

Potential industry use cases that require secure and instantaneous decision coordination, enabled by Quantum Sync, include: finance for high-frequency trading for synchronizing decisions across multiple trading sites, defense for coordination of systems in mission-critical environments, distributed robotics and artificial intelligence (AI) for coordinating actions between nonlocal robots, and AI agents without relying on classical communication.

By enabling robust entanglement connectivity not only are we enhancing existing classical applications, but we are also paving the way for transformative quantum solutions. Through the unified quantum networking software stack and demonstrations from Quantum Sync and Quantum Alert, we can see the foundation for classical quantum integration and the emergence of novel quantum-enabled applications.

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