Bansilal Ramnath Agarwal Charitable Trust's
Vishwakarma Institute of Technology
(An Autonomous Institute affiliated to Savitribai Phule Pune University)

DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING (ARTIFICIAL INTELLIGENCE & MACHINE LEARNING)

CSE(AI&ML)- SPECTRUM

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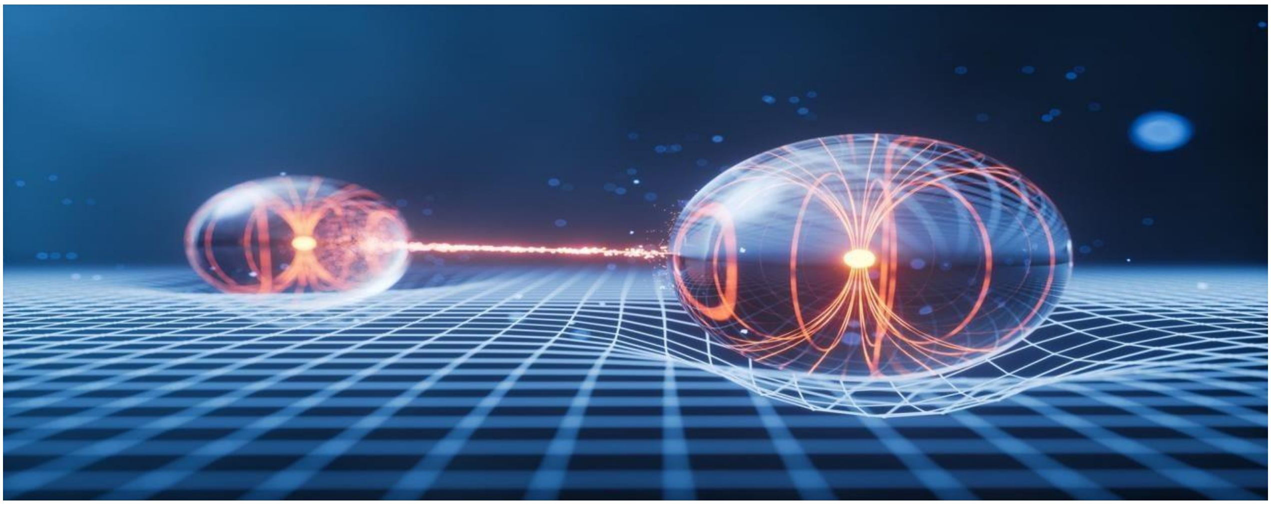
Quantum Internet: The Next Evolution of Connectivity

Vishwakarma Institute of Technology, Pune

Welcome to the September 2025 edition of the CSE(AI&ML) on Quantum Internet: The Next Evolution of Connectivity!

In this monthly publication, we're excited to bring you the latest advancements in Quantum Internet. This edition explores new era of communication with Quantum computing. Quantum Internet is poised to be one of the most groundbreaking technological advancements of the 21st century. Unlike today's classical internet, which transmits information using electrical signals and binary bits (0s and 1s), the Quantum Internet leverages the strange and powerful principles of quantum mechanics. It uses quantum bits (qubits), which can exist in multiple states simultaneously (superposition), and harnesses entanglement to achieve ultra-secure, lightning-fast communication.



INTRODUCTION

The Quantum Internet represents a revolutionary leap in the way humans communicate and share information. Unlike the classical internet, which relies on transmitting bits of information in the form of 0s and 1s through electrical signals, radio waves, or fiber optics, the Quantum Internet harnesses the principles of quantum mechanics. Here, information is carried not by classical bits but by quantum bits (qubits) units of information that can exist in multiple states at once due to the principle of superposition. The key enabler of this new type of network is quantum entanglement, a phenomenon where two particles become linked in such a way that the state of one instantly affects the state of the other, no matter the distance between them. This property allows information to be transmitted with unprecedented levels of security and speed. In simpler terms, the Quantum Internet is not just a "faster" version of today's internet. It is a fundamentally new paradigm of communication, capable of solving problems that classical communication networks never can.

Limitations of Classical Internet:

- Security Concerns:Classical encryption (like RSA or AES) depends on mathematical problems that are difficult to solve using today's computers.

- Speed Bottlenecks: Even with technologies like 5G and fiber optics, classical data transfer still involves copying and transmitting bits in a linear manner. Data congestion, latency, and physical infrastructure create bottlenecks.
- Trust Issues in Data Transmission: In classical networks, you can never be 100% sure that data hasn't been intercepted or tampered with during transmission. The Quantum Internet, however, can guarantee if eavesdropping has occurred, thanks to the laws of physics.

BRIEF HISTORY OF QUANTUM COMMUNICATION

The development of the Quantum Internet is not an overnight invention, it is the result of decades of research:

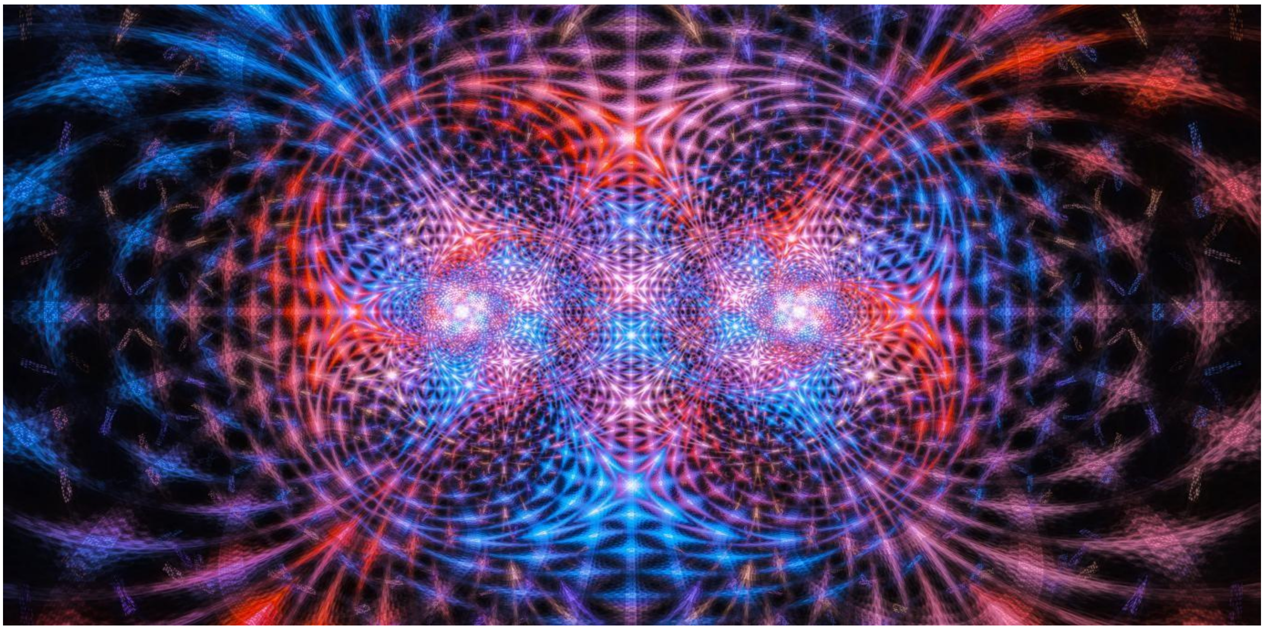
- 1960s–1970s: Quantum mechanics gained strong experimental validation. Ideas of using quantum states for communication started appearing.

- 1984: The first theoretical proposal of Quantum Key Distribution (QKD) was published by Charles Bennett and Gilles Brassard (BB84 protocol). This laid the foundation for secure communication using quantum mechanics.
- 1990s: Proof-of-concept experiments demonstrated the feasibility of transmitting quantum keys over short distances using fiber optics.
- 2016: China launched the world's first quantum satellite (Micius), enabling quantum communication between ground stations thousands of kilometers apart.
- 2020s: The U.S. Department of Energy released a blueprint for a national Quantum Internet. The EU and India also began major quantum initiatives.This history shows that we are now at the cusp of moving from experimental prototypes to real-world deployment.

OPPORTUNITIES IN NEAREST FUTURE

For engineering students, the Quantum Internet is not just "theory."
It is a career-defining technology of the next decades. Just as the classical internet created opportunities in networking, software development, cybersecurity, AI, and IoT, the Quantum Internet will open new doors in:

1. Quantum Networking & Cybersecurity
2. Quantum Software & Algorithms
3. Quantum Hardware Engineering (optics, cryogenics, chips)
4. Interdisciplinary Roles (AI + Quantum, IoT + Quantum)
5. Understanding this technology early will give students an edge in academia, research, and industry, preparing them to become part of the next technological revolution.



Applications:

1. Unbreakable Communication Security

- Quantum Key Distribution (QKD): Enables two parties to share encryption keys with *provable security* based on quantum mechanics.
- Any eavesdropping attempt disturbs the quantum states, making interception detectable.
- Application: Government, military, banking, and healthcare secure communication.

2. Global Quantum Communication

- Extends secure quantum communication over long distances using quantum repeaters and satellites.
- Application: Connecting quantum computers, research labs, and industries across the globe.

3. Distributed Quantum Computing

- Multiple quantum computers can be connected to solve problems collaboratively.
- Allows resource sharing, error correction, and parallel processing.
- Application: Solving problems in chemistry, physics, AI, and optimization that are too complex for a single quantum computer.

4. Quantum Cloud Computing

- Users can access remote quantum computers securely via the quantum internet.
- Application: Companies and researchers without their own quantum hardware can still run quantum algorithms.

5. Enhanced Sensing & Metrology

- Distributed quantum sensors can synchronize via QI for extreme precision.
- Application:
  - Navigation without GPS
  - Climate and earth monitoring
  - Astronomy (linking telescopes into a global quantum array).

6. Fundamental Science

- Enables experiments in quantum physics over long distances.
- Application: Testing quantum entanglement, relativity, and even gravity effects on quantum information.

ADVANTAGES & DISADVANTAGES

Advantages:

1. **Unbreakable Security**
   - Quantum Key Distribution (QKD) ensures theoretically hack-proof communication.
   - Any eavesdropping is instantly detectable.
2. **Global Secure Communication**
   - Governments, banks, defense, and hospitals can communicate without fear of interception.
3. **Enabling Distributed Quantum Computing**
   - Connects multiple quantum computers to work together, making them more powerful.
4. **Quantum Cloud Access**
   - Ordinary users and researchers can use quantum computing power remotely.
5. **Ultra-Precise Synchronization**
   - Atomic clocks and sensors connected by QI can achieve nanosecond-level synchronization.
   - Useful for navigation, financial transactions, and astronomy.
6. **Boost for Science & Innovation**
   - Helps test fundamental physics theories (entanglement, relativity, gravity's effect on quantum info).
   - Opens pathways for new technologies.

Disadvantages

1. **High Cost & Complexity**
   - Requires **specialized hardware** (photon sources, quantum repeaters, superconducting devices).
   - Extremely expensive to build and maintain.
2. **Fragility of Quantum States**
   - Quantum information is highly sensitive to noise and loss in fiber cables or air.
   - Needs cryogenic cooling and precise conditions.
3. **Limited Distance Without Repeaters**
   - Photons carrying quantum info decay over long distances.
   - Still a challenge to scale to a **global quantum network**.
4. **Technology Immaturity**
   - Quantum repeaters, error correction, and large-scale networks are still under research.
   - Practical deployment may take decades.
5. **Not a Replacement for Classical Internet**
   - QI will **complement**, not replace, the existing internet.
   - It's focused on **security and specialized computing**, not faster Netflix streaming.
6. **Skilled Workforce Requirement**
   - Needs quantum engineers, cryptographers, and physicists.
   - Currently, the expertise pool is very limited.

CAREER PATHS

1. Quantum Physicist / Research Scientist

- **Focus:** Quantum mechanics, entanglement, quantum communication protocols.
- **Skills Needed:** Physics, quantum optics, mathematics, experimental setups.
- **Where:** Universities, research labs, government institutes (CERN, MIT, IITs, IISc, etc.).

2. Quantum Software Engineer

- **Focus:** Algorithms, quantum networking protocols, simulation of quantum communication.
- **Skills Needed:** Python, Qiskit, Cirq, quantum algorithms, cryptography.
- **Where:** Tech companies (IBM, Google, Microsoft, AWS, Xanadu, startups).

3. Quantum Cryptographer

- **Focus:** Quantum Key Distribution (QKD), post-quantum cryptography, network security.
- **Skills Needed:** Cryptography, quantum information theory, cybersecurity.
- **Where:** Defense, banking, government security agencies.

4. Quantum Hardware Engineer

- **Focus:** Building quantum repeaters, photon detectors, superconducting circuits.
- **Skills Needed:** Electrical engineering, materials science, cryogenics, optics.
- **Where:** Hardware labs, telecom companies, national labs.

5. Quantum Network Architect

- **Focus:** Designing hybrid classical + quantum internet infrastructure.
- **Skills Needed:** Network engineering, quantum communication protocols, telecom.
- **Where:** Telecom operators, internet backbone providers, R&D companies.

6. Quantum Optics & Photonics Engineer

- **Focus:** Photon sources, optical fibers, quantum entanglement experiments.
- **Skills Needed:** Optics, photonics, laser physics, nanotechnology.
- **Where:** Photonics companies, quantum startups, space agencies (for satellite QI).

7. Academic / Teaching Path

- **Focus:** Educating the next generation in quantum technologies.
- **Skills Needed:** Teaching + research in physics, computer science, or engineering.
- **Where:** Universities, online education platforms, research institutes.

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