Course Title: Quantum Networks and Communication

Credit Hrs: **3**

Prerequisite: Linear Algebra and Probability Theory, Quantum Mechanics, Classical Communication Theory or Information Theory

Course Description:

The course includes an introduction to quantum mechanics and information theory, detailed exploration of quantum communication protocols (e.g., teleportation, QKD), network architecture and design principles, and experience with quantum network simulation tools. The course helps to understand, analyze, and build quantum networks for applications like secure communication and distributed quantum computing.

Course Objectives:

- Introduce fundamental concepts of quantum communication and networking.
- Explain how quantum entanglement enables secure and efficient data transmission.
- Explore quantum key distribution (QKD) and other quantum cryptographic protocols.
- Understand the design and operation of quantum repeaters and quantum internet architectures.
- Implement and simulate simple quantum communication protocols using modern software tools.

Course Learning Outcomes: Upon successful completion, students will be able to:

- Explain and model quantum communication processes (teleportation, superdense coding, QKD).
- Analyze architectures and components of quantum networks.
- Evaluate performance, security, and fidelity in quantum communication channels.
- Simulate and test quantum communication protocols using Qiskit, NetSquid, or similar tools.
- Apply quantum networking concepts to emerging technologies such as distributed quantum computing and secure communications.

Course Contents:

Week	Contents
1-2	Introduction to Quantum Communication: Motivation and overview of quantum communication vs classical communication, Quantum bits, superposition, entanglement, and measurement, Quantum information theory basics: qubit entropy, fidelity, channel capacity
3–4	Quantum Teleportation & Superdense Coding: Quantum teleportation protocol and its implementation, Superdense coding and efficiency analysis, Entanglement as a communication resource
5–6	Quantum Cryptography & Quantum Key Distribution (QKD): BB84, B92, and E91 protocols, Security proofs and attack models, Experimental QKD systems and real-world deployments,
7–8	Quantum Channels and Noise Models: Quantum channel models (depolarizing, amplitude damping, phase damping), Quantum error correction codes, Entanglement fidelity and channel capacities
9–10	Quantum Repeaters and Entanglement Swapping: Limits of direct quantum communication, Quantum repeater design, purification, and swapping, Long-distance entanglement distribution
11–12	Quantum Network Architectures: Quantum network stack and layers, Quantum routers, memories, and synchronization issues, Distributed quantum computing and quantum internet vision
13	Quantum Communication Protocols and Standards: Quantum authentication and secret sharing, Post-quantum cryptography vs quantum cryptography, International projects and standardization efforts (ETSI, ITU, DARPA)
14	Experimental Implementations: Fiber-based and satellite-based quantum communication, Micius satellite mission and intercontinental QKD, Hardware technologies: photonic qubits, ion traps, NV centers
15	Network Simulation and Real-world Testing: Simulation tools (NetSquid, QuNetSim, Qiskit Aer), Performance analysis and error modeling, Case study: building a small-scale quantum network simulator

16	Current Research and Future Directions: Quantum internet roadmap, Integration with classical networks, Emerging trends: quantum blockchain, 5G-QKD, and hybrid communication, Student project presentations

Textbooks/ References:

- *"Quantum Computation and Quantum Information"* — Nielsen & Chuang (2010)
- *"Quantum Communication and Information Technologies"* — Alexander Sergienko (2005)
- Pirandola, S. et al., *"Advances in Quantum Cryptography"*, *Advances in Optics and Photonics* (2020)
- Kimble, H. J., *"The Quantum Internet"*, *Nature* (2008)
- Gisin, N., & Thew, R. *"Quantum Communication"*, *Nature Photonics* (2007)
- Qiskit Quantum Communication tutorials
- NetSquid Simulator documentation
- Quantum Internet Alliance (QIA) project reports
- ETSI QKD standard documentation

Assessments:

- Assignments: 10%
- Quizzes: 10%
- Midterm Exam: 30%
- Final Exam: 50%