Research Plan: Automated Design Framework for Networked Quantum Artificial Intelligence and Its Applications

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Objective

This project aims to develop and prototype a modular design automation framework that supports the configuration, simulation, and evaluation of networked quantum artificial intelligence (QAI) systems. The goal is to provide a foundational tool for automating the design of scalable, distributed quantum AI models over quantum network infrastructures.

Week-by-Week Plan

Week 1: Background Study and Onboarding

- **Reading Materials**:
  - Basics of quantum computing (NISQ era, qubit models, entanglement)
  - Intro to quantum machine learning (QML) frameworks (e.g., Qiskit Machine Learning, PennyLane, Qamomile)
  - Concepts in quantum networking (entanglement distribution, quantum repeaters, teleportation)
  - Review of AI in distributed systems (federated learning, agent-based AI)
- **Hands-on Setup**:
  - Setup of dev environment (Python, Qiskit/PennyLane/Qamomile, networkx, QuTiP)
  - Run basic quantum circuit and QML examples on simulators
- **Goal**: Interns establish foundational knowledge of QML and quantum networks

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Week 2: Problem Definition and System Modeling

- Formalize the system architecture of networked QAI:

    - Nodes (quantum processors), links (quantum channels), control plane (classical coordination)
- Define key automation tasks:
    - Network-aware model deployment
    - Resource allocation (qubits, entanglement bandwidth)
    - AI model partitioning across nodes
- **Deliverable**: System architecture diagram + component specification

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Week 3: Design Automation Tool Prototyping – Part 1

- Build first module: Network Topology Parser & Simulator
    - Input: Graph-based network topology
    - Output: Simulated fidelity and link delay under various entanglement regimes
- Build second module: Quantum Resource Allocator
    - Greedy or ML-based mapping of quantum circuits across distributed nodes
- **Deliverable**: Working simulation backend with simple CLI

Week 4: Design Automation Tool Prototyping – Part 2

- Implement QAI Model Deployment Logic:
    - Simple models (e.g., Quantum SVM, Quantum CNNs) assigned across network nodes
    - Optimization strategies for communication cost and qubit usage
- Integrate with previous modules to form a pipeline
- **Deliverable**: End-to-end demo on 2–4 node network with QML workload

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Week 5: Evaluation and Benchmarking

- Evaluate the framework's automation logic with test cases:
    - Varying network sizes, models, and error conditions
- Metrics: performance, fidelity, latency, scalability
- Compare automated design against manual baseline
- **Deliverable**: Technical report on design performance

Week 6: Documentation and Final Presentation

- Consolidate codebase and write user documentation
- Prepare project presentation: demo, findings, limitations

- Discuss future extensions:
  - Integration with real quantum backends (e.g., IBM Quantum)
  - ML-driven circuit decomposition and routing strategies
  - Support for quantum-classical hybrid control loops

Supervision and Guidance

- **Weekly Check-ins**: Progress tracking, Q&A, design feedback
- **Midweek Office Hours**: For debugging and mentoring
- **Collaborative Tools**: GitHub repo, shared drive, Slack/Teams channel

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Plans for Future Work

- Extend the framework to include:
  - Support for larger-scale quantum networks (10+ nodes)
  - Realistic noise models and quantum error mitigation
  - Application-specific pipelines (e.g., quantum sensor networks, quantum-enhanced edge AI)
- Potential publication in journals/conferences such as IEEE Quantum, QCE, or Nature npj Quantum Information