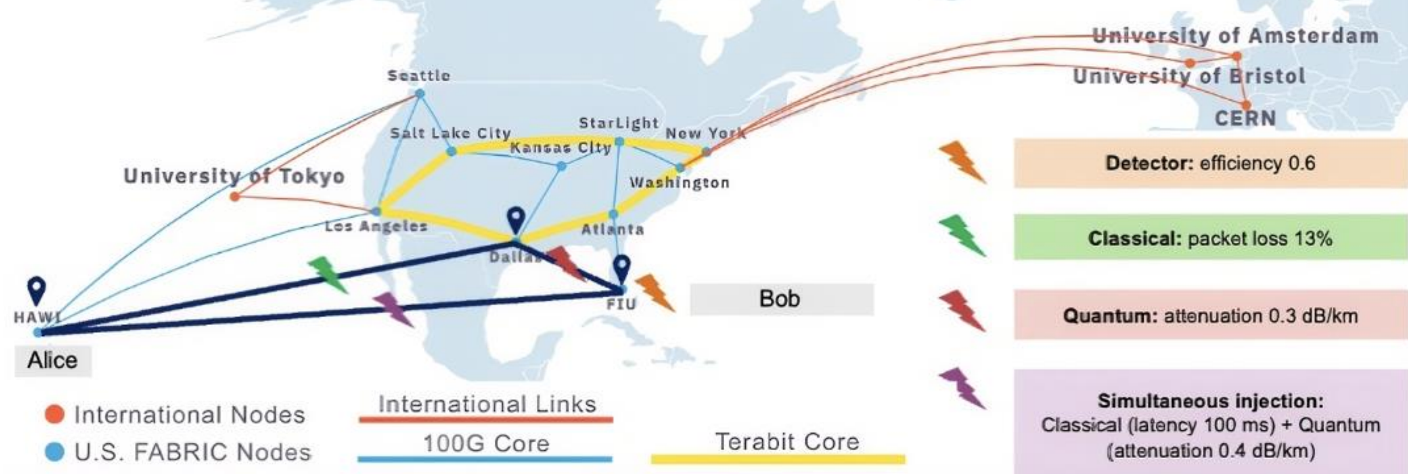

Quantum Networks Fault Injection
Undergraduate Research Assistant

As hybrid quantum-classical systems expand across high-performance computing networks, hardware failure modes and silent security bottlenecks present major reliability challenges. Building on our QFabric quantum-network emulation platform for BB84 quantum key distribution (QKD), this project scales empirical fault injection from the FABRIC testbed to production-grade hybrid QKD-PQC deployments spanning 29 US sites and international links. We will deploy agentic AI to model propagation paths of faults, detect cross-layer anomalies across the classical, quantum, and detector channels, and evaluate the security of large distributed encryption workloads.

A qualified Physics, Computer Science, Math, Statistics, or Systems student will evaluate large-scale network and quantum telemetry from FABRIC and apply agentic reasoning to diagnose complex QKD failures under real-world conditions. The team is led by Dr. Phuong Cao at the National Center for Supercomputing Applications (NCSA) in collaboration with DEPEND group at ECE/CSL.

Role: Collect QKD execution traces and network telemetry on FABRIC, build agentic orchestrators for multi-layer fault injection (latency, jitter, packet loss, attenuation, and silent data corruption), and quantify reliability anomalies across large distributed quantum network runs.

Skills: Strong programming background (e.g., Python, C++) and familiarity with Linux networking are required. Experience with cryptography, quantum networks (e.g., BB84, QKD), network emulation (tc-netem, FABRIC), or agentic frameworks is preferred.

Benefits: Independent study course credit; co-authorship on systems and security publications; direct access to the FABRIC testbed and NCSA compute allocations and other supercomputers, unlimited (fair-use) of large-scale language model tokens – both frontier and self-hosted trillion parameter LLMs. Previous students have successfully transitioned into SpaceX (xAI), Meta, Microsoft AI, Google DeepMind, etc., to continue the collaboration.

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About the project & team: Phuong Cao | https://go.illinois.edu/phuong-cao

Input: Fault parameter space:

$$\boldsymbol{\Theta} = \boldsymbol{\Theta}_c \times \boldsymbol{\Theta}_q \times \boldsymbol{\Theta}_d$$

where $\boldsymbol{\theta}_c = (\text{delay}, \text{jitter}, \text{loss})$, $\boldsymbol{\theta}_q = (\alpha, L, p_f)$, $\boldsymbol{\theta}_d = (\eta, \lambda_d)$. Here α is attenuation (dB/km), L distance (km), p_f polarization fidelity, η detector efficiency, and λ_d dark count rate (Hz), with outcome functions:

$$\text{QBER} : \boldsymbol{\Theta} \to [0,1], \qquad \text{KeyRate} : \boldsymbol{\Theta} \to [0, \infty)$$

Failure Set:

$$F = \{(\boldsymbol{\theta}_c, \boldsymbol{\theta}_q, \boldsymbol{\theta}_d) \in \boldsymbol{\Theta} : \text{QBER}(\boldsymbol{\theta}) \geq 0.11 \vee \text{KeyRate}(\boldsymbol{\theta}) = 0\}$$

Goal: Empirically characterize ∂F across $\boldsymbol{\Theta}$ using real FABRIC WAN infrastructure, identifying thresholds that diverge from ideal-channel simulators.