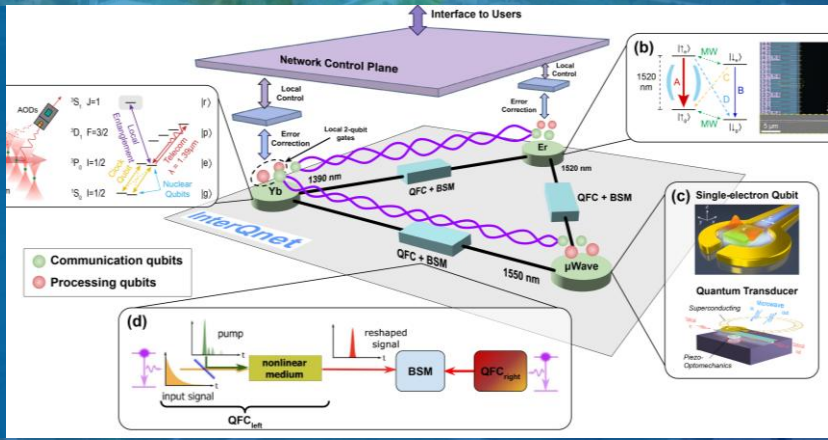
IETF 124 QIRG MEETING – NOV 3, 2025

INTERQNET: A HETEROGENEOUS FULL-STACK APPROACH TO CO-DESIGNING SCALABLE QUANTUM NETWORKS



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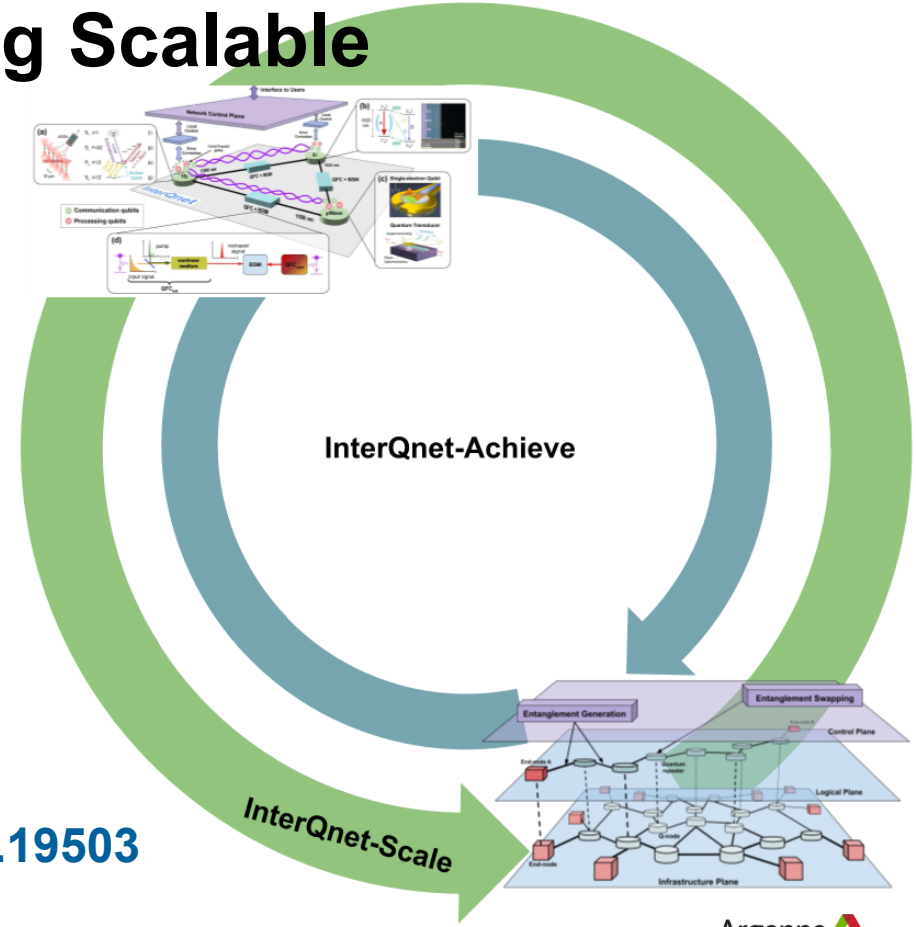
InterQnet: A Heterogeneous Full-Stack Approach to Co-designing Scalable Quantum Networks

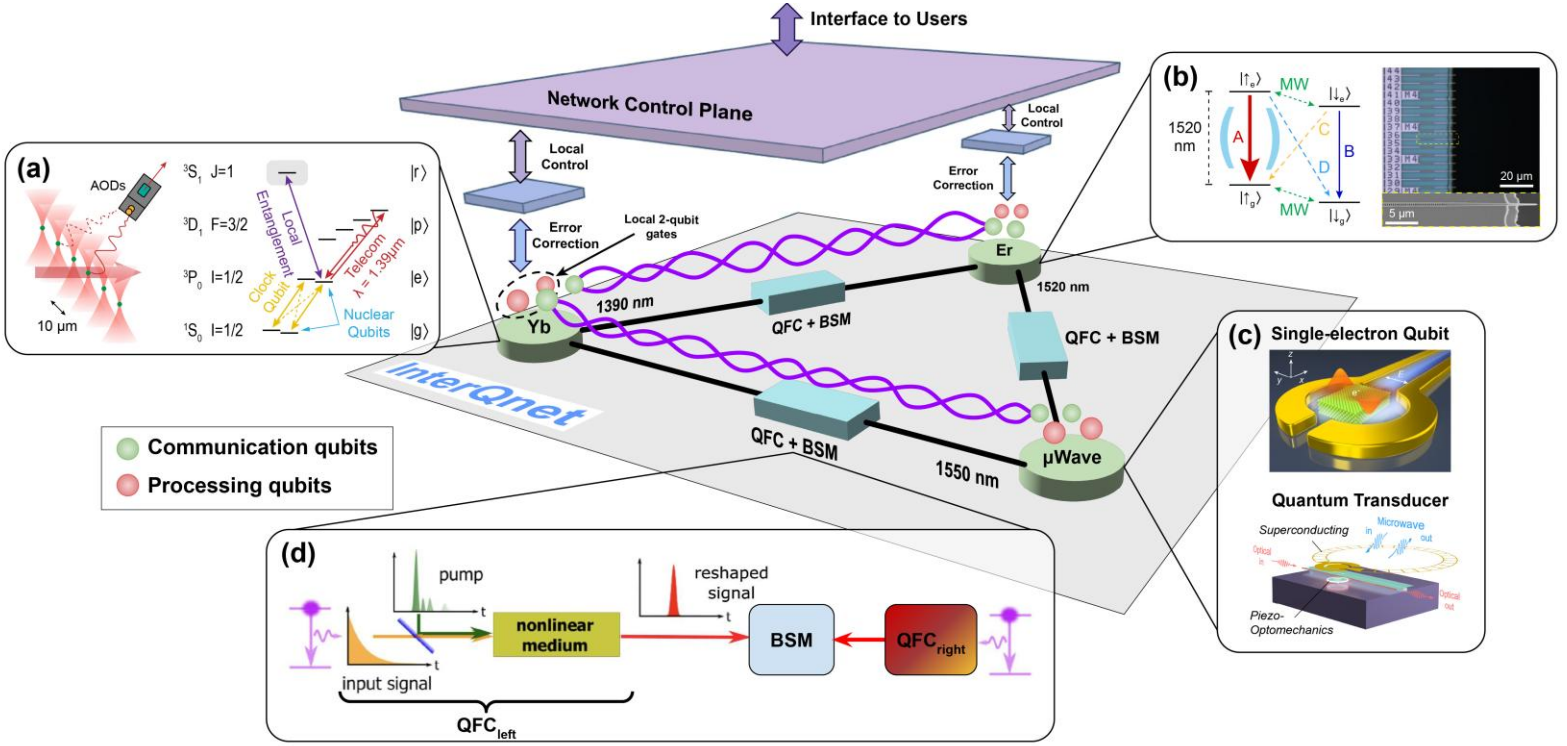
- Advance the state of the art in scalable quantum communications
- Realize two interrelated overarching goals:
  - **InterQnet-Achieve** – Practical realization of a full-stack heterogeneous quantum network
  - **InterQnet-Scale** – Systems study of a scalable quantum network architecture



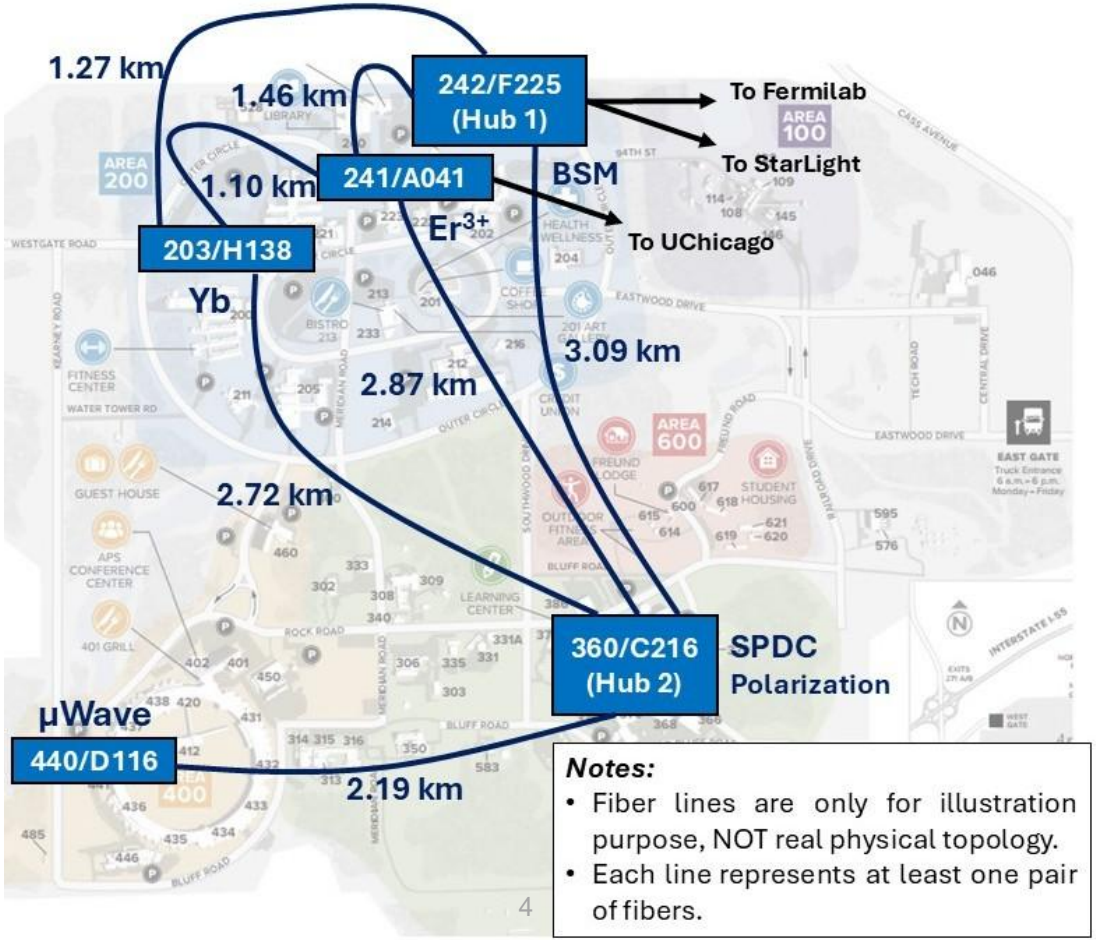
arXiv:2509.19503

InterQnet-Achieve

Integrating Heterogeneous Qubit Platforms Developed at Argonne

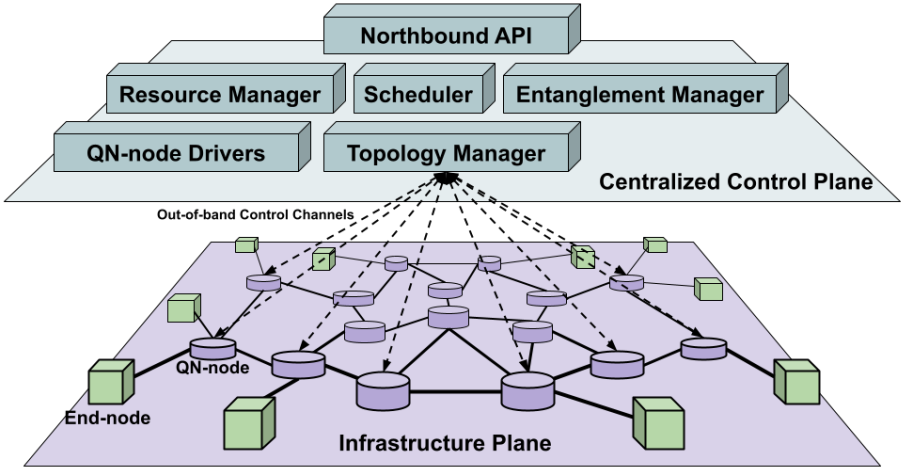


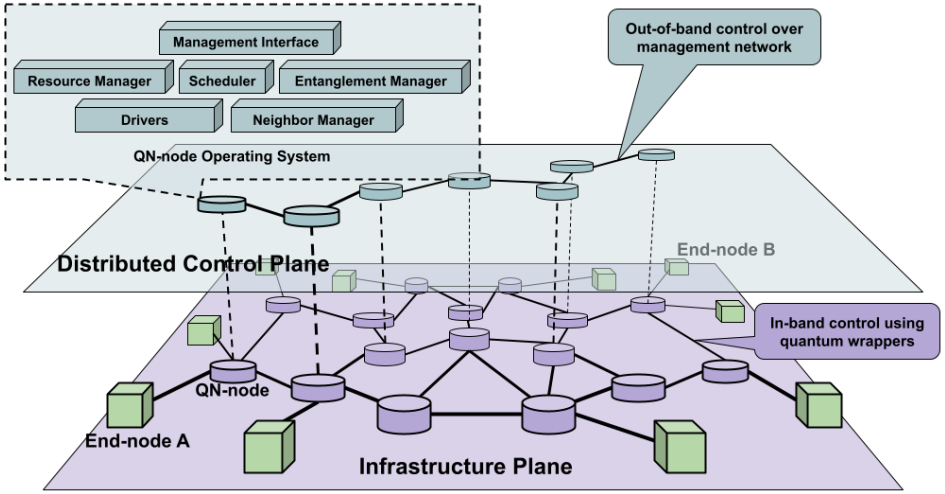
ARGONNE QUANTUM NETWORK



InterQnet-Scale

Systems Study of a Scalable Quantum Network Architecture





Centralized control with out-of-band control channels

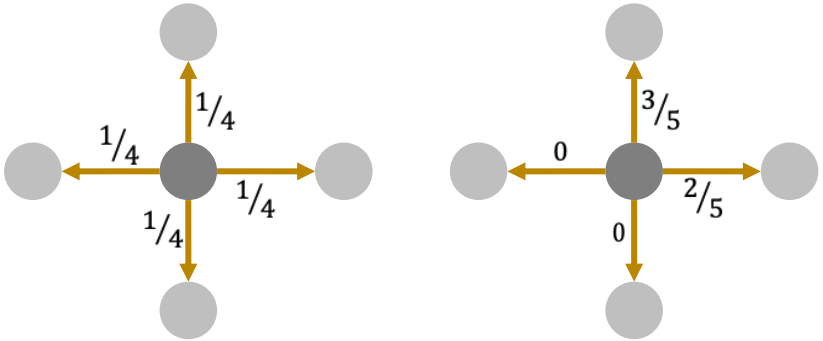
Distributed control with either out-of-band over management network or in-band control using quantum wrappers

DESIGN AND SIMULATION OF THE ADAPTIVE CONTINUOUS ENTANGLEMENT GENERATION PROTOCOL

C. Zhan, J. Chung, A. Zang, A. Kolar, and R. Kettimuthu, "Design and simulation of the adaptive continuous entanglement generation protocol," in 2025 International Conference on Quantum Communications, Networking, and Computing (QCNC), pp. 127–134, 2025.

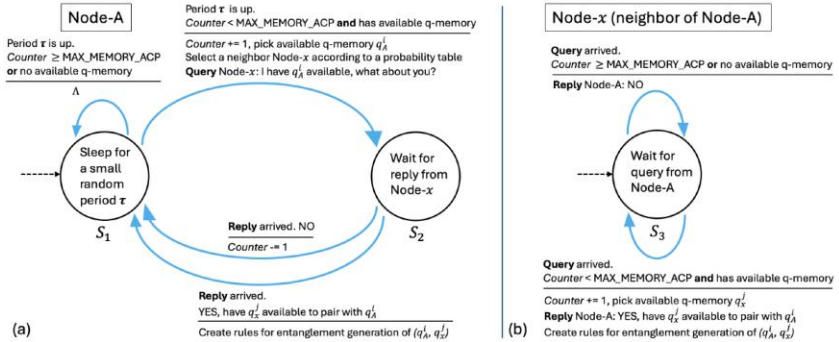
INTRODUCTION

- **Goal:** Reduce the time to generate a remote EP requested from users
- Continuously generate EPs between neighbor nodes in the background, independent of user requests.
- Design an adaptive scheme to guide nodes in selecting neighbors in a smarter way by leveraging *past user request information*



W/O request information

With request information

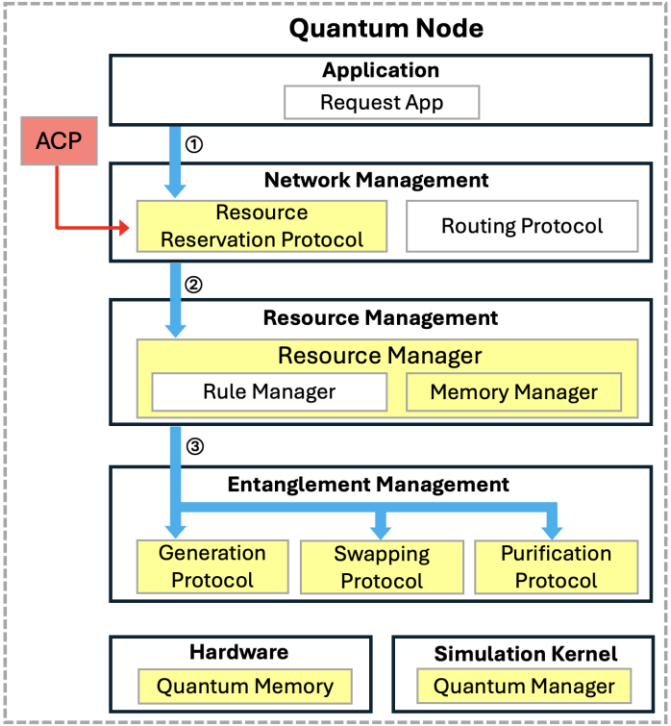


ACP IMPLEMENTATION SEQUENCE SIMULATOR

SEQUENCE

Quantum Networking in SeQUeNCe: Customizable, Scalable, Easy Debugging

- We make extensions to 5 modules (yellow colored) of SeQUeNCe to support the development of ACP (red colored)



SIMULATION SETUP

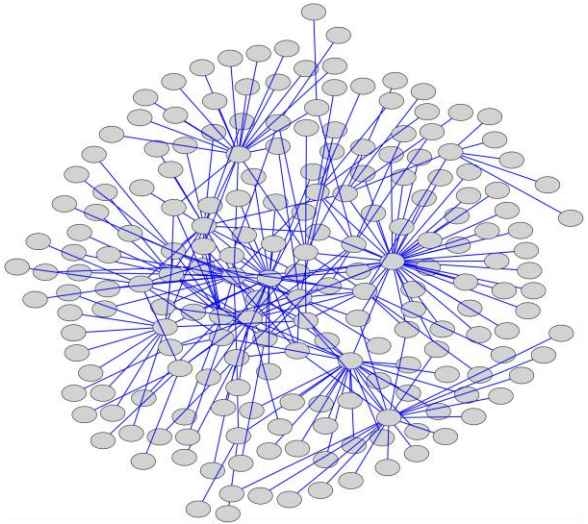
- Figure of merit: Time-to-serve (TTS), fidelity
- Methods compared:
  1) Adaptive Continuous Protocol (ACP): includes purification on the link EPs generated by ACP. Has two variants without purification: pick the freshest EP & pick a random EP
  2) On-demand-only (ODO): start generating the EPs after the request is made
  3) Uniform Continuous Protocol (UCP): Non-adaptive Continuous Protocol
- Classical latency $l_{(u,v)} = \frac{d_{(u,v)}}{c} + hop_{(u,v)} \times D_{forwarding} + D_{end\ processing}$
- Request's initiator and responder are sampled from a traffic matrix.

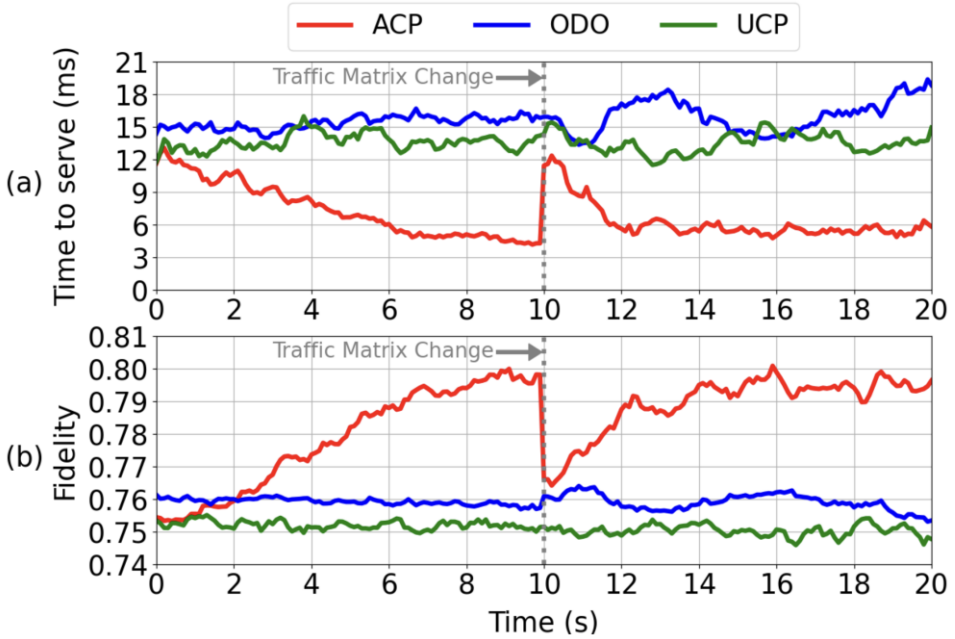
TABLE I
SIMULATION PARAMETER

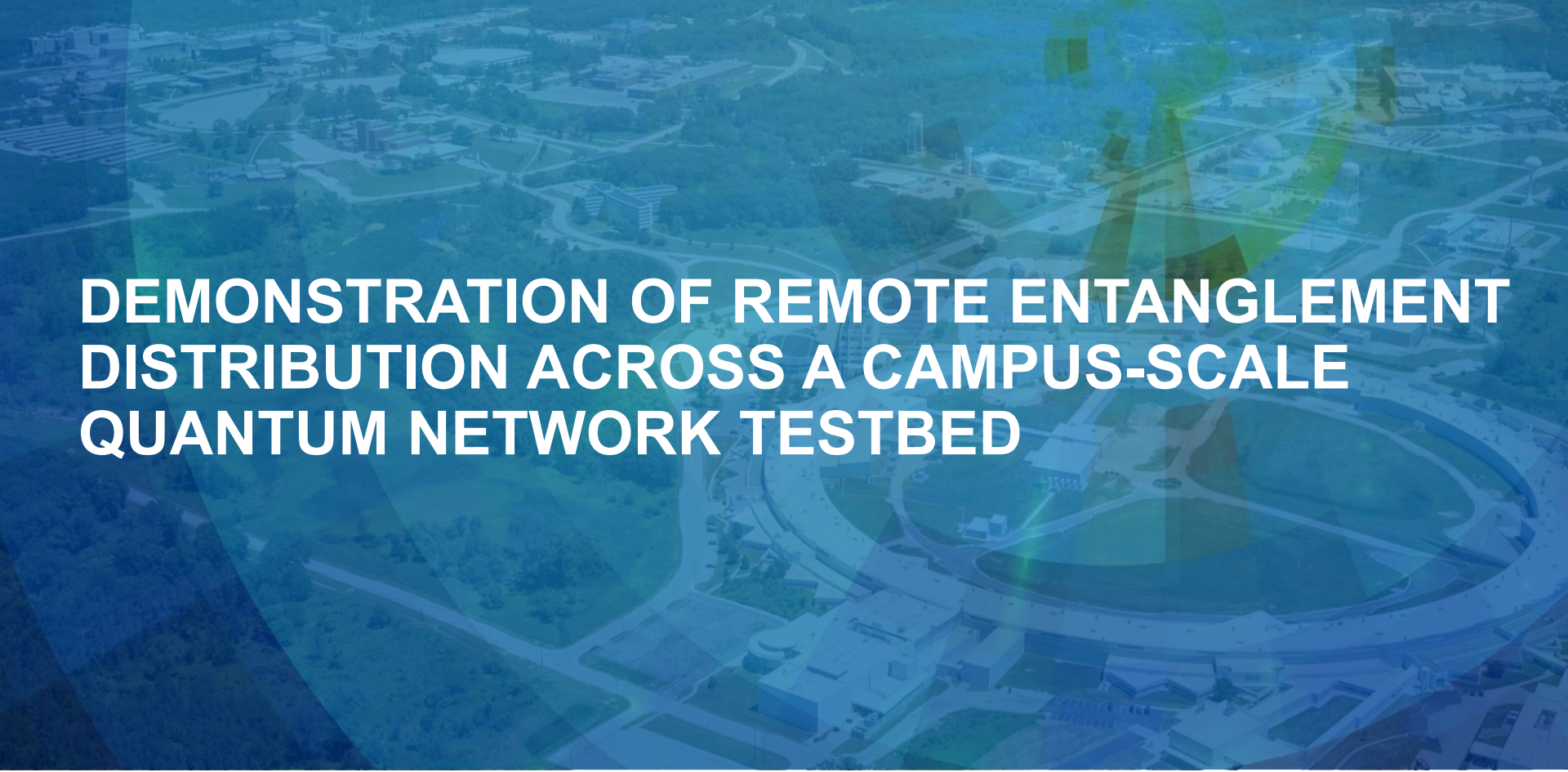
End node processing delay	100 μs	Forward delay	20 μs
# of memory per node	10	Fiber attenuation	0.2 dB/km
Max # of memory for ACP	5	Link distance	10 km
Quantum memory efficiency	0.6	Speed of light	2e8 m/s
Photon detector efficiency	0.95	Coherence time	2 s
Initial EP fidelity	0.95	Pauli errors	$[\frac{1}{3}, \frac{1}{3}, \frac{1}{3}]$
Swapping success rate	1	Gate fidelity	0.99
Photonic BSM success rate	0.5	Measure fidelity	0.99
Request arrival rate	10 Hz	δ in Algo. 1	0.05

SIMULATION OF 200 NODE AUTONOMOUS SYSTEM

1) ACP improves the TTS. TTS is reduced by 50% and 57% (**6.8 ms** vs. 13.6 ms vs. 15.7 ms) compared to UCP and On-demand-only.
2) ACP improves the fidelity compared to UCP and On-demand-only (**0.8** vs. 0.76 vs. 0.75)





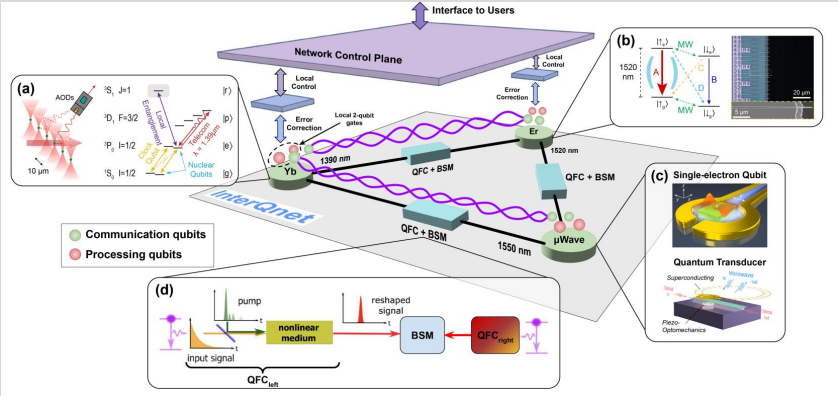


DEMONSTRATION OF REMOTE ENTANGLEMENT DISTRIBUTION ACROSS A CAMPUS-SCALE QUANTUM NETWORK TESTBED

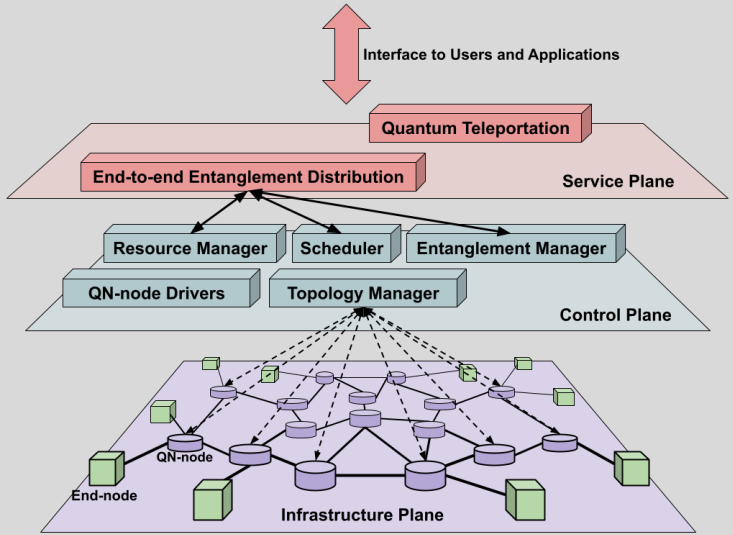
CONTROL PLANE ARCHITECTURE

InterQnet-Achieve

Practical realization of a full-stack heterogeneous quantum network

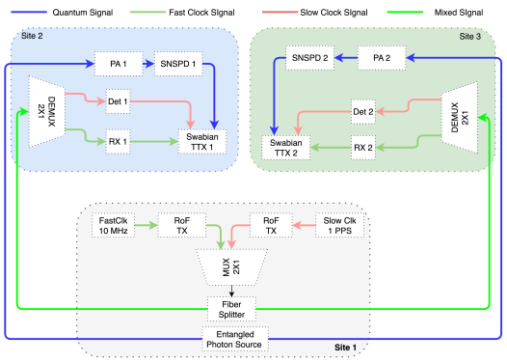


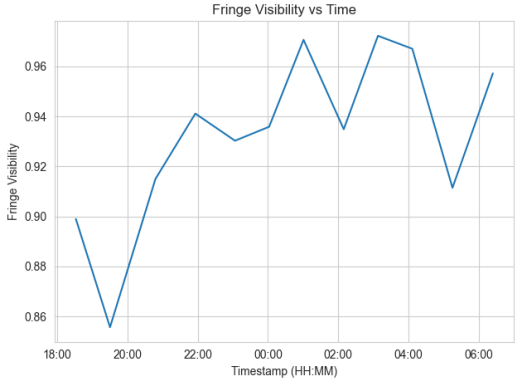
Plane Abstraction

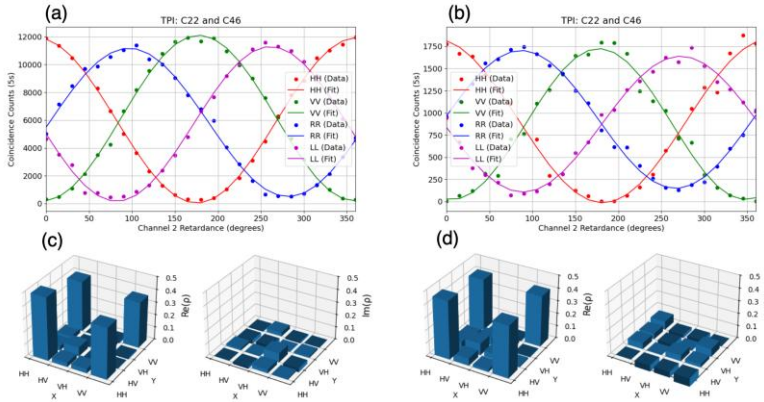


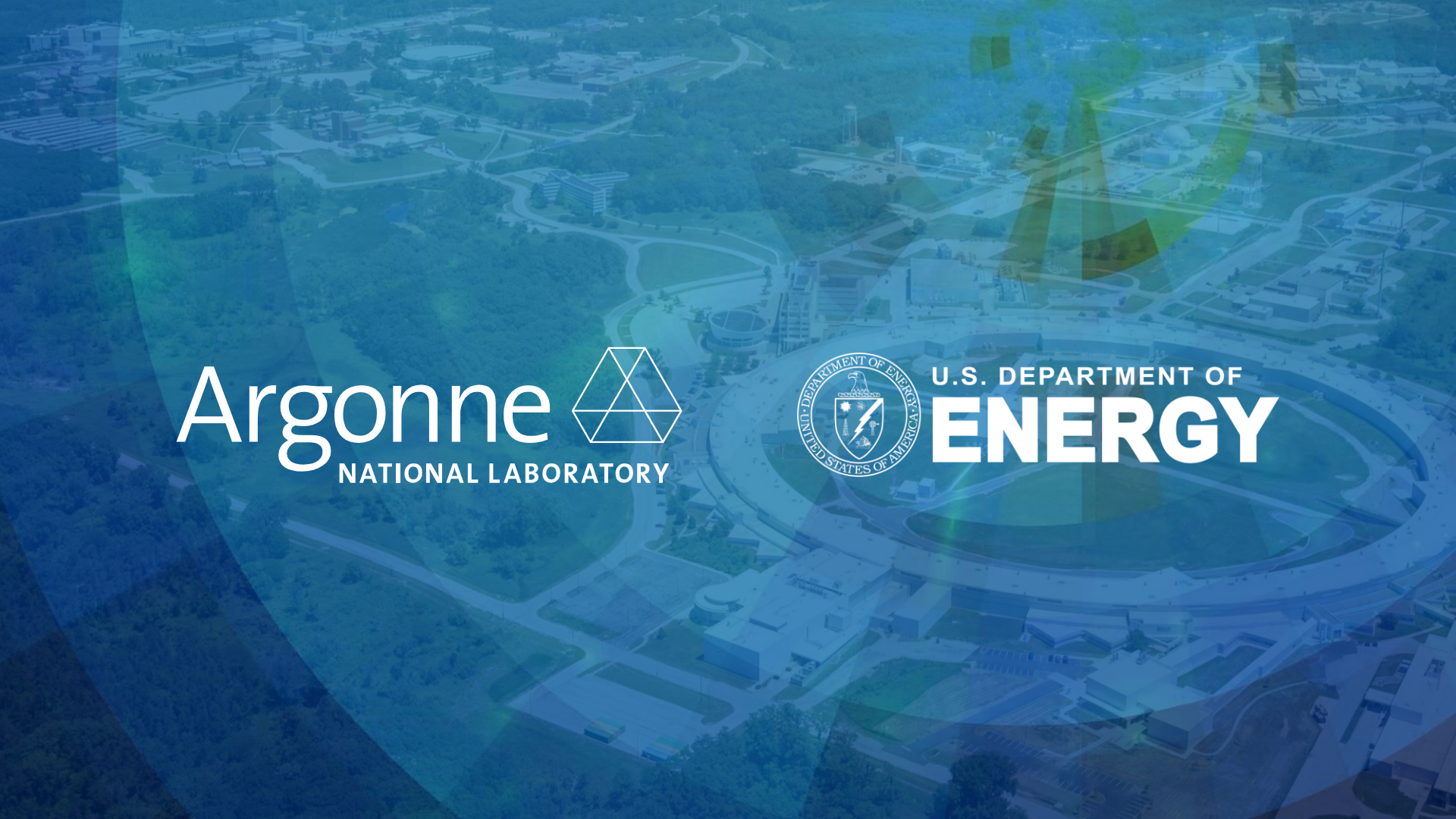
PROTOTYPE AND PRELIMINARY RESULTS

- **Implementation:**
  - Agents enable remote control of devices (e.g., EPS, SNSPD, all-optical switches, and time taggers)
  - RF over Fiber custom clock synchronization system
  - Communication over gRPC
  - Centralized control, automated calibration, and continuous operation
- **Evaluation:**
  - Two-photon interference and Quantum state tomography
  - Observed fringe visibility ~95%





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