Controlling Quantum Networks From Dynamics to Applications

S&T Campaign: Computational Sciences
Advanced Computing Architectures

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Research Objective

- **To develop a framework for implementing quantum networks, from the top level classical control layer down to the quantum control of hardware, and to explore the applications of quantum networks.**

Challenges

- **Simulating quantum networks. This task is challenging due to the dynamics of the network links and the large Hilbert spaces that result.**
- **Designing networks to perform specific functions, such as optimal entanglement distribution or sensing**

Approaches

- **Programmable Quantum Networking**
- **Identify and modify OpenFlow attributes to support quantum metadata network communications**
- **Develop programmable multi-node quantum network topology simulations**
- **Simulation of network hardware**
- **Use an automated approach to obtaining dynamical equations from network structure (e.g. QHDL)**
- **Use MPS methods for handling imperfections such as time-delays in network links**
- **Control methods for network elements**
- **Simulate network nodes with input wave-forms and use optimal control techniques to realize elementary network functions such as routing and frequency conversion**

ARL Facilities and Capabilities Available to Support Collaborative Research

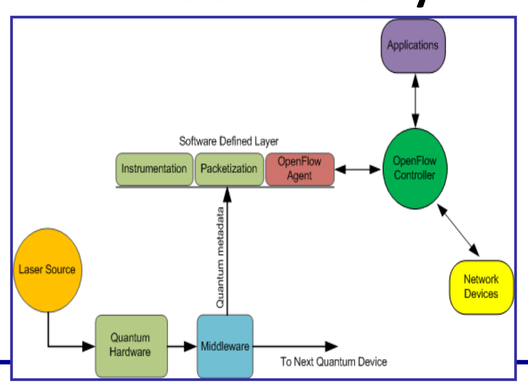
- **Theory team with expertise in quantum measurement, quantum control, software-defined networking, parallel programming**
- **Large array of supercomputers and support staff**
- **ARL is building an optical entanglement Lab to support this Research effort.**

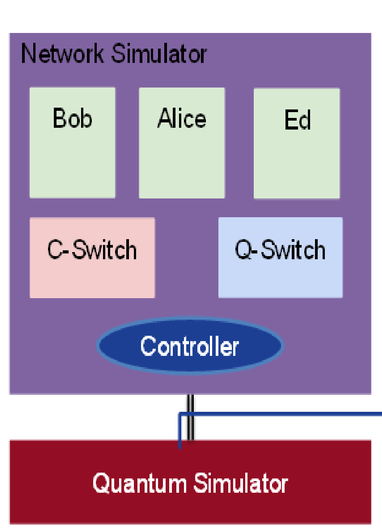
Expertise/Facilities/Capabilities Sought in Collaboration

- **Complementary expertize in open systems, simulation algorithms and methods, and approximation methods.**
- **Quantum Entanglement Lab facilities at APG**

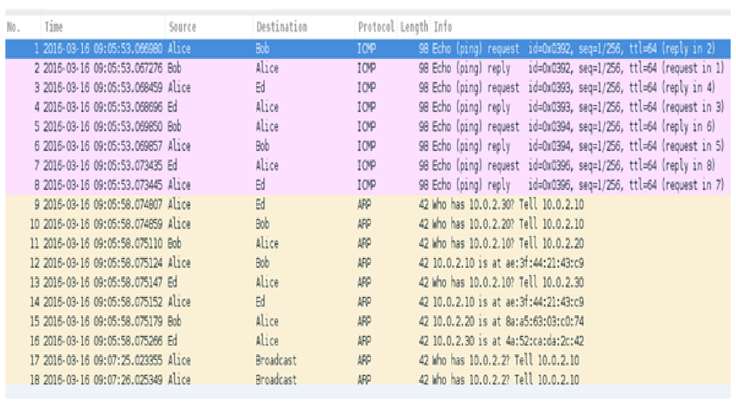
References

- **Breuer and Petruccione, The Theory of Open Quantum Systems (OUP, Oxford, 2007).**
- **Dasari, VR and Sadlier RJ, et al (2016) "Programmable Multi-Node Quantum Network Design and Simulation" arXiv:1604.01276**
- **Dasari, VR and Humble, TS (2016) "OpenFlow Arbitrated Programmable Network Channels for Managing Quantum Metadata" arXiv:1512.08545**
- **Eisert, Browne, Scheel, Plenio, Annals of Physics 311, 431 (2004)**





Mininet environment with nodes and switches connected to quantum network simulator



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  3 2016-03-16 09:05:53.068459 Alice   Ed           ICMP     98 Echo (ping) request  id=0x0393, seq=1/256, ttl=64 (reply in 4)
  4 2016-03-16 09:05:53.068696 Ed      Alice        ICMP     98 Echo (ping) reply    id=0x0393, seq=1/256, ttl=64 (request in 3)
  5 2016-03-16 09:05:53.069850 Bob     Alice        ICMP     98 Echo (ping) request  id=0x0394, seq=1/256, ttl=64 (reply in 6)
  6 2016-03-16 09:05:53.069857 Alice   Bob          ICMP     98 Echo (ping) reply    id=0x0394, seq=1/256, ttl=64 (request in 5)
  7 2016-03-16 09:05:53.073435 Ed      Alice        ICMP     98 Echo (ping) request  id=0x0396, seq=1/256, ttl=64 (reply in 8)
  8 2016-03-16 09:05:53.073445 Alice   Ed           ICMP     98 Echo (ping) reply    id=0x0396, seq=1/256, ttl=64 (request in 7)
  9 2016-03-16 09:05:58.074807 Alice   Ed           ARP      42 Who has 10.0.2.30? Tell 10.0.2.10
 10 2016-03-16 09:05:58.074859 Alice   Bob          ARP      42 Who has 10.0.2.20? Tell 10.0.2.10
 11 2016-03-16 09:05:58.075110 Bob     Alice        ARP      42 Who has 10.0.2.10? Tell 10.0.2.20
 12 2016-03-16 09:05:58.075124 Alice   Bob          ARP      42 10.0.2.10 is at ae:3f:44:21:43:c9
 13 2016-03-16 09:05:58.075147 Ed      Alice        ARP      42 Who has 10.0.2.10? Tell 10.0.2.30
 14 2016-03-16 09:05:58.075152 Alice   Ed           ARP      42 10.0.2.10 is at ae:3f:44:21:43:c9
 15 2016-03-16 09:05:58.075179 Bob     Alice        ARP      42 10.0.2.20 is at 8a:a5:63:03:c0:74
 16 2016-03-16 09:05:58.075266 Ed      Alice        ARP      42 10.0.2.30 is at 4a:52:ca:da:2c:42
 17 2016-03-16 09:07:25.023355 Alice   Broadcast    ARP      42 Who has 10.0.2.2? Tell 10.0.2.10
 18 2016-03-16 09:07:26.025349 Alice   Broadcast    ARP      42 Who has 10.0.2.2? Tell 10.0.2.10
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Wireshark running on mininet nodes and DSPY running on quantum simulator capture complete quantum network behavior

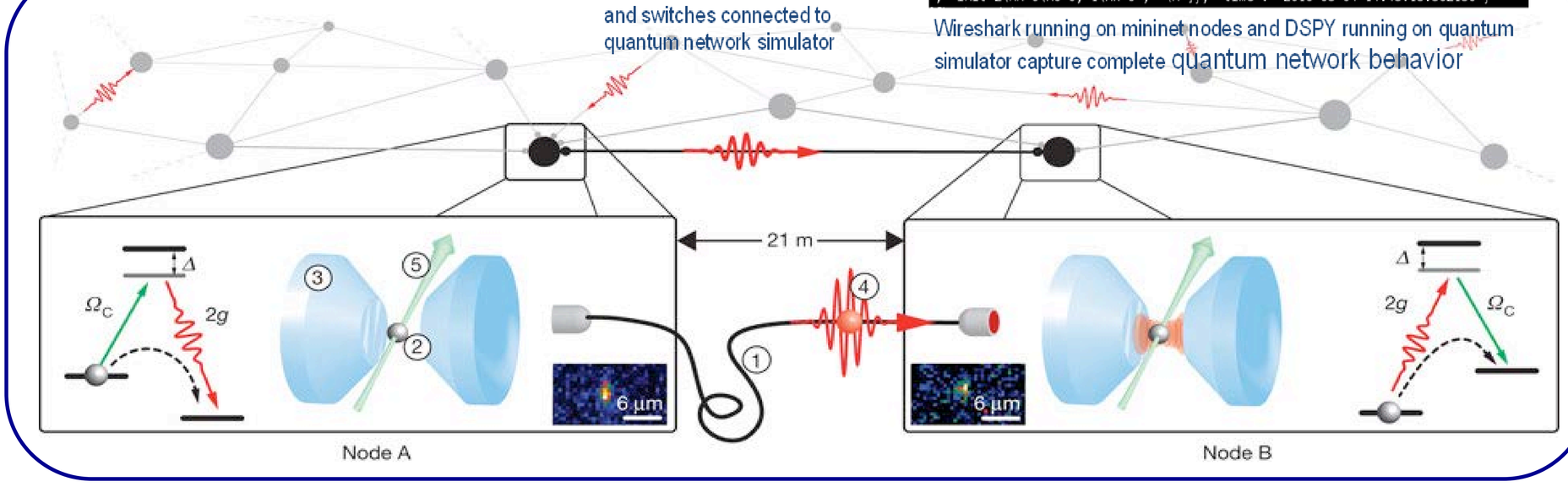

Figure Captions

a. **Programmable 3-node quantum network Simulation**

b. **Programmable quantum quantum node model**

c. **Schematic diagram of a quantum network with a single atom at each node (Rempe group, Nature (2012)).**