Chicago Network Operators Group

Juniper Networks | Engineering Simplicity

Why Entangle? How? How many hops?

(aka Link-State Protocol Support for Multihop Entanglement)

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Draft in QIRG/IRTF

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https://tools.ietf.org/html/draft-kaws-qirg-advent-03

Quantum Networking Hackathon at RIPE77

- Unusual outcome: an exploration of what it takes to create good entanglement pairs

- How this information can be shared across the quantum network to enable good “path computation”

Entanglement

- A peculiarly quantum phenomenon
  - Leads to special networking features not available to classical networks
- Creating “good” entanglement would thus be nice
  - What does “good” entanglement mean?
  - What do you need to make it?

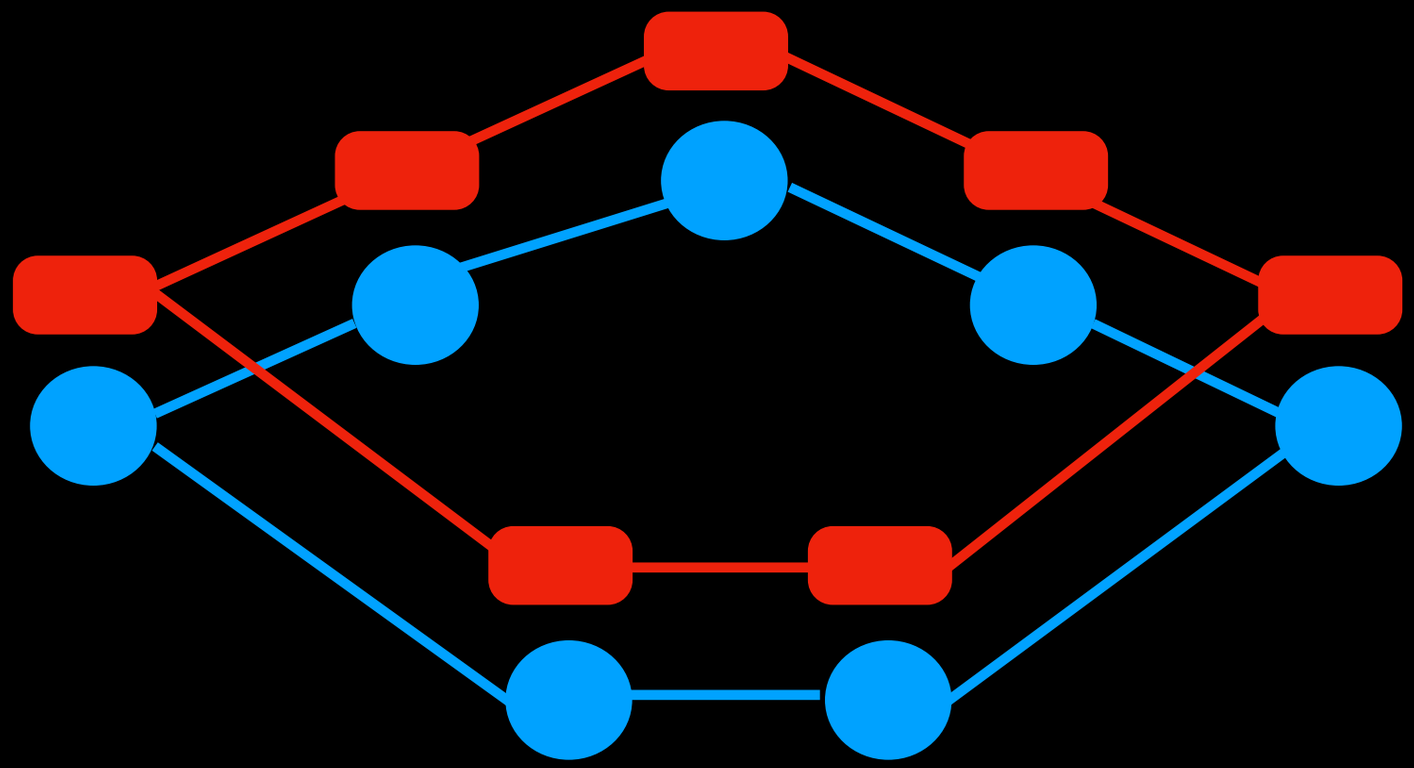
Why Entangle?

- Quantum Key Distribution (QKD) lets two parties share a random secret key (e.g., as a private key for AES) (https://en.wikipedia.org/wiki/Quantum_key_distribution)
- Entanglement enables QKD in such a manner that eavesdropping can be detected
- QKD is not a means of encryption, just a means of sharing a key (analogous to Diffie-Hellman)

State of the Art

- Researchers at QuTech and the Kavli Institute have demonstrated entanglement at a distance of 1.3km (https://www.sciencealert.com/quantum-spookiness-has-been-confirmed-by-first-loophole-free-experiment)
  - Work is ongoing to do this at 10+km
- Researchers have also demonstrated deterministic entanglement “on demand” at 10Hz at a distance of 2m (https://www.sciencealert.com/new-production-line-method-for-quantum-entanglement-on-demand)
  - This is needed for networks of >2 nodes

Basics



CQN

Quantum link

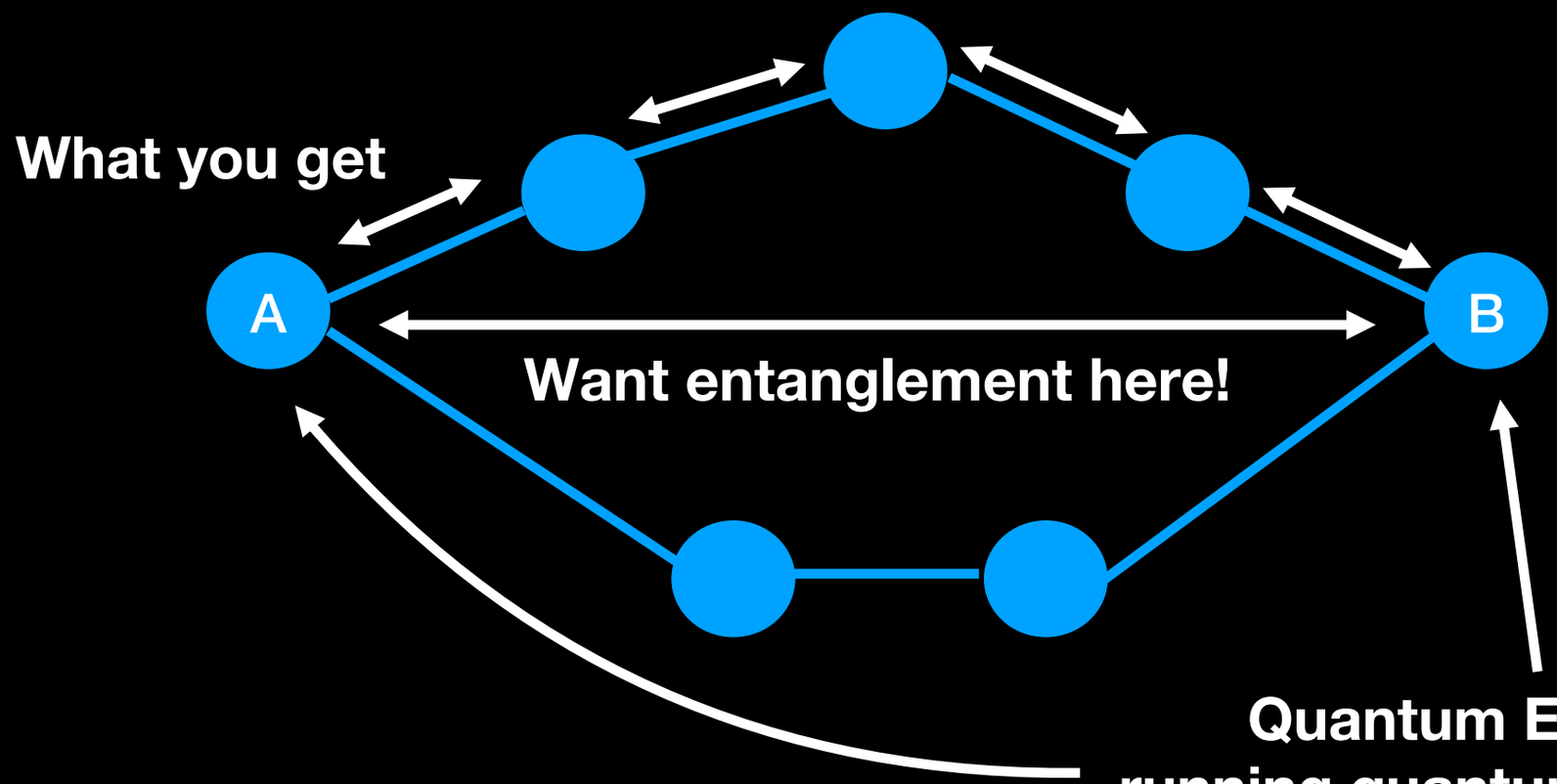
Classical (control) node

Classical link

Classical network parallels the quantum network

Classical nodes initiate quantum operations on the quantum nodes

Making Entanglement



Or you could take the southern route

Are they even more paths from A to B?

Which would be best?

What tradeoffs are available on each path?

Questions

- What is the topology of the quantum network?
- What are the capabilities of each node?
  - # c-qubits, #s-qubits, operations?
- What are the capabilities of each quantum link?
  - How good an entanglement can it make; how fast?
  - Do I have to distill to make it better?
- Can the entanglements across links be joined to a “multi-hop” entanglement between the QENs?
  - Are more multihop entanglements needed for distillation?

Proposal

- Run a link-state protocol on the classical nodes
  - Classical network topology = quantum topology
- Add entanglement capability TLVs to the link-state protocol
  - Each control node learns the entanglement capability of all nodes and links in the quantum network
  - It’s now possible to compute paths for multihop entanglement, probabilities of success, need for distillation, etc.

Properties Under Consideration

- Fidelity-time tradeoffs (link)
- Total # c-qubits, # s-qubits (node)
  - Available #s would be nice, but expensive
- Qubit operations possible (node)
- Distillation schemes possible (node)

Fidelity measures the quality of entanglement

c-bits are communication qubits; s-bits are storage qubits

Some properties are for a node, others for a link

One can distill multiple entanglements to create a single one of higher fidelity

Next Steps for draft

- Lots of work to do on the draft
  - Ensure it captures AdvEntCap for multiple realizations of traveling qubits (currently focused on NV-center in diamond)
    - Feedback from folks working on ion trap-based and other realizations would be very welcome!
- Need draft with the detailed formats/encaps in LSR WG
- Prototype code???
- Lessons to be learned/extrapolation from QuTech's proposed 2-hop entanglement experiments in lab and in the wild