Quantum Ping

Shota Nagayama (Mercari, Inc.)
Shigeya Suzuki (Keio Univ.)
Hirotaka Nakajima (Mercari, Inc.)

Topics Addresses in the Hackathon

- Bringing concepts of routing and forwarding to the quantum network
  - The Classical Internet Protocol is not suitable
  - We worked on adapting classical concepts (MPLS, etc …)
  - Implemented forwarding in a simulated network
- Quantum Ping
  - How to measure the quality of the quantum connection
  - Defining the specification of quantum ping
  - Figuring out the requirements to to establish a quantum ping
- Blockchain integration in Quantum networks
  - Proof of entanglement as a more resource efficient mechanism for consensus

https://github.com/IETF-Hackathon/ietf104-project-presentations

What we did in the Hackathon

- Define Quantum Ping

- Writing the (to appear in IETF105)

Quantum Networking

- Quantum plane (data plane)
  - create entanglements between adjacent nodes
  - operate entanglement swapping for multi-hop routing
  - error management
- Classical plane (control/management plane)
  - create session
  - resource management of nodes on an entire path between the end nodes

What is the Reachability in classical communication networks

- Reachability refers to the ability that a pair of nodes at least once succeed to communicate datagrams in both directions.
- This “succeed” confirms
  - The nodes on the entire path between the two nodes have ability to forward messages in the proper direction. (the paths of the round trip does not matter)
  - Those nodes have consistent and proper routing table.

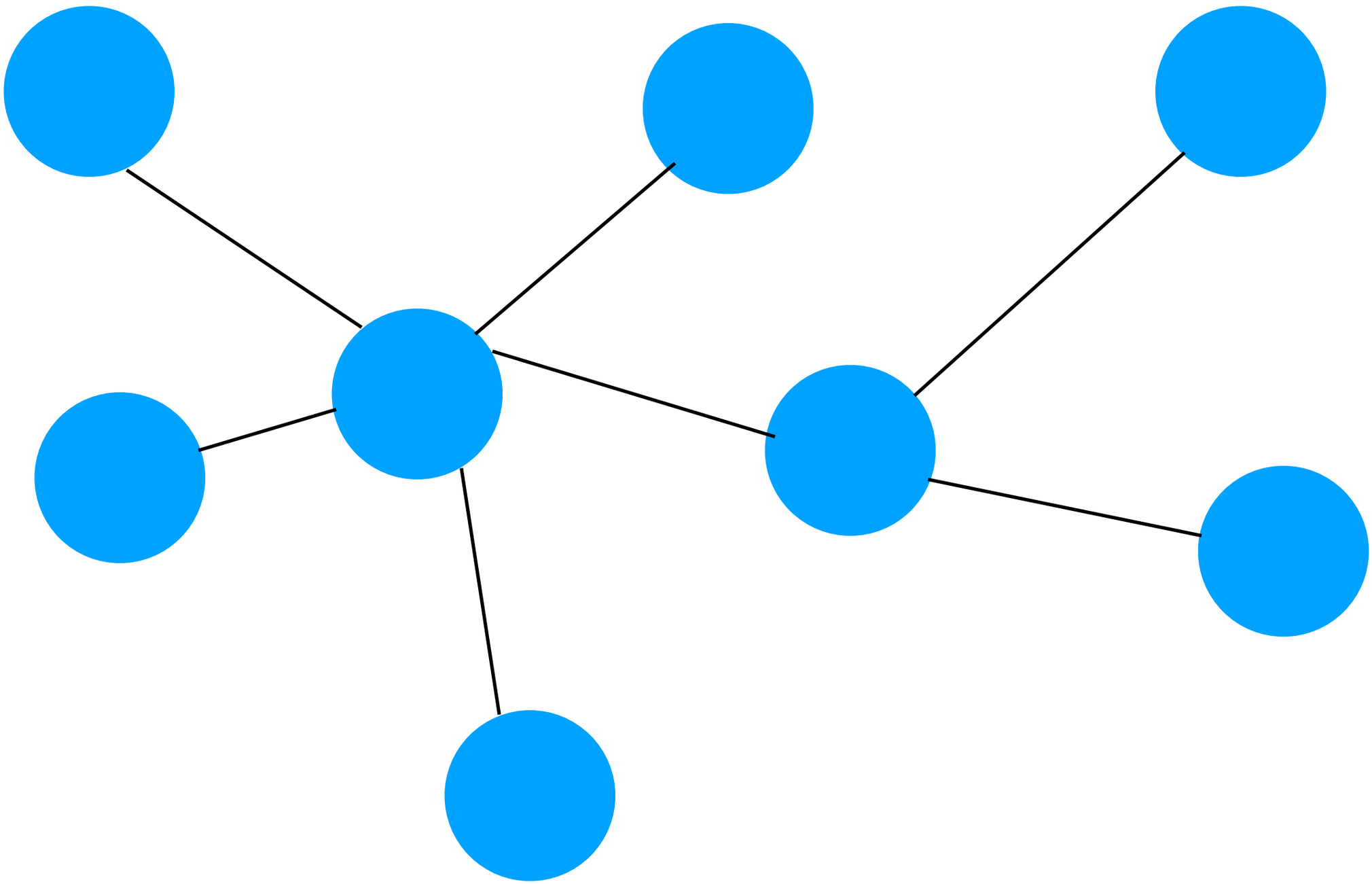
What should be the Reachability in quantum communication networks

- should be the same as the classical one for consistency.
- Reachability refers to the ability that a pair of nodes at least sometimes succeed to generate Bell pairs.
  - This “succeed” confirms
    - The nodes on the entire path between the two nodes have ability to execute entanglement swapping between the two proper quantum network interfaces.
    - Those nodes have consistent and proper routing table.
    - Bell pairs with sufficient fidelity (a measure of errors) is generated.

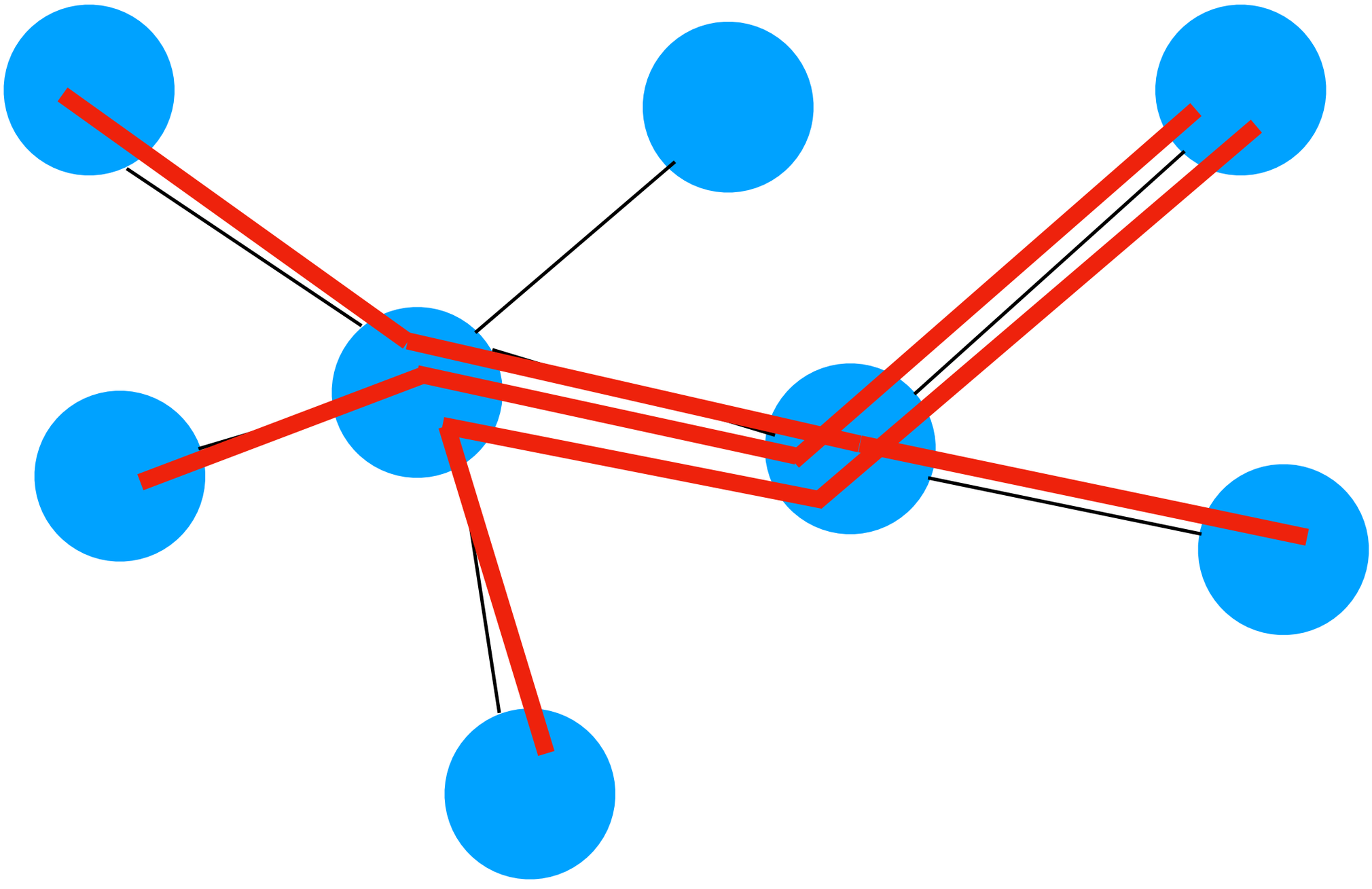
Problem in quantum

- The cost of a Bell pair is **soooooooooooooooo** expensive.

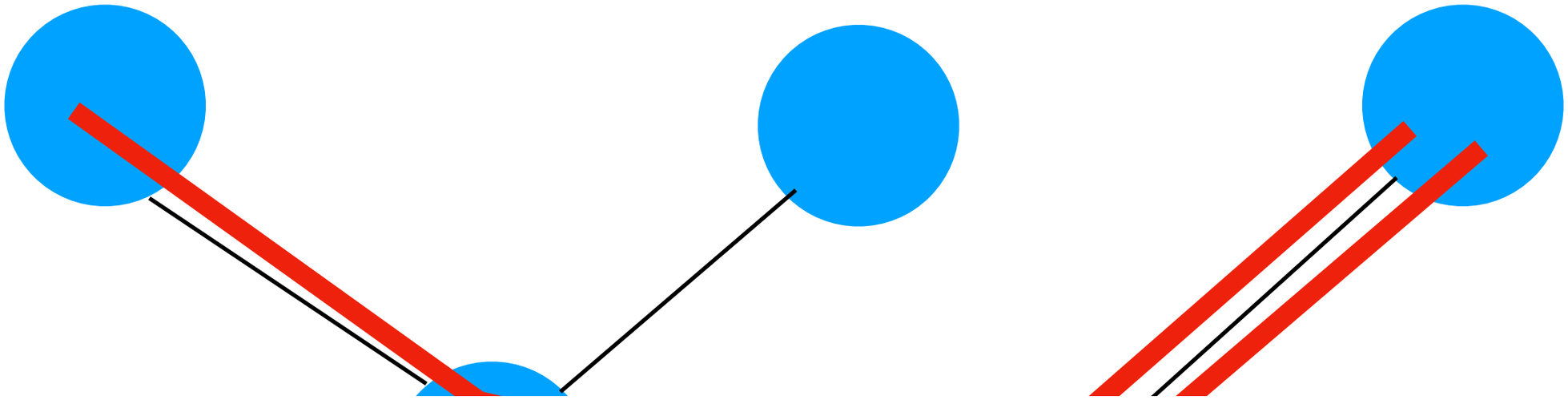
We want to avoid full state tomography



We want to avoid full state tomography



We want to avoid full state tomography



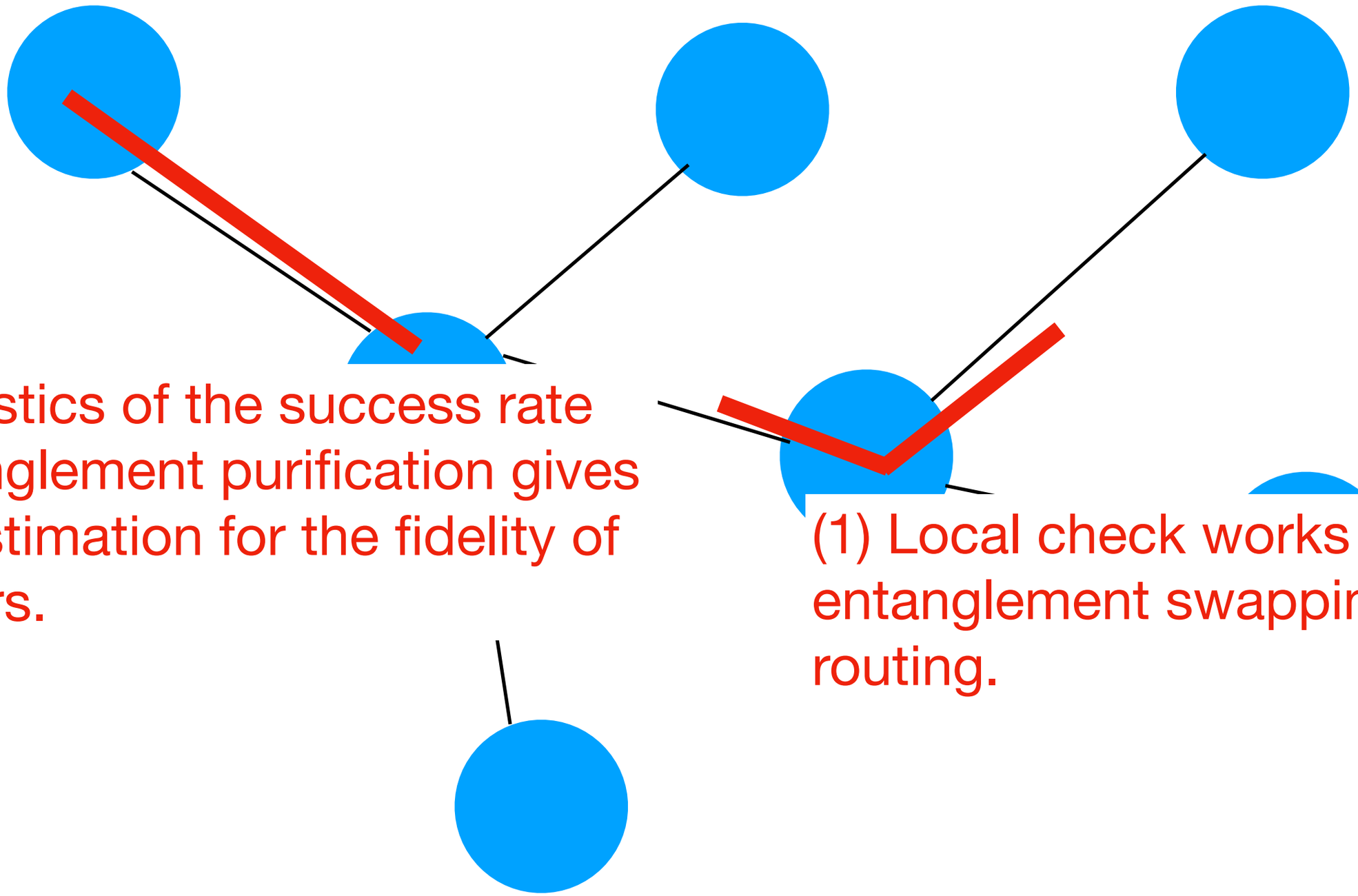
Do we want to fulfill the network with quantum ping?

No, I don’t.

What should be the Reachability in quantum communication networks

- should be the same as the classical one for consistency.
- Reachability refers to the ability that a pair of nodes at least sometimes succeed to generate Bell pairs.
  - This “succeed” confirms
    - The nodes on the entire path between the two nodes have ability to (1) execute entanglement swapping between the two proper quantum network interfaces.
    - Those nodes have consistent and proper routing table.
    - (2) Bell pairs with sufficient fidelity (a measure of errors) is generated.

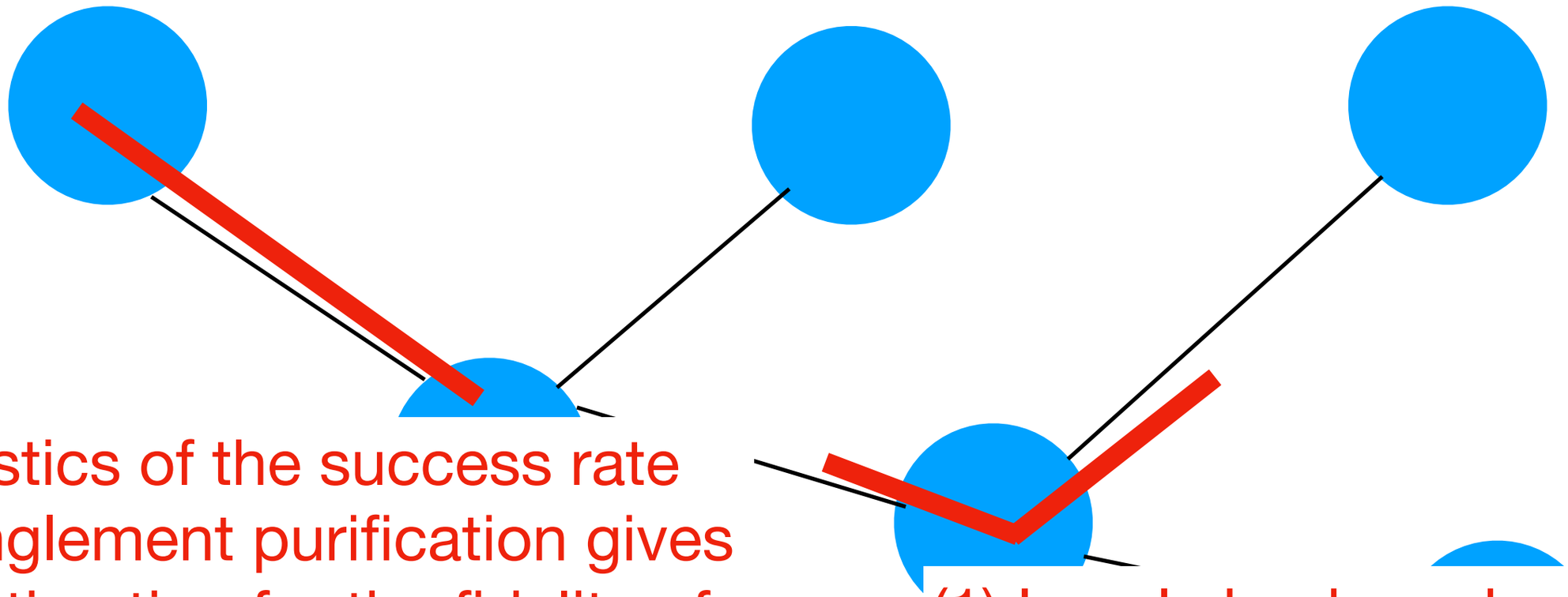
Proposed method:
local health-check as quantum ping



(2) Statistics of the success rate of entanglement purification gives good estimation for the fidelity of Bell pairs.

(1) Local check works in entanglement swapping for routing.

Proposed method:
local health-check as quantum ping

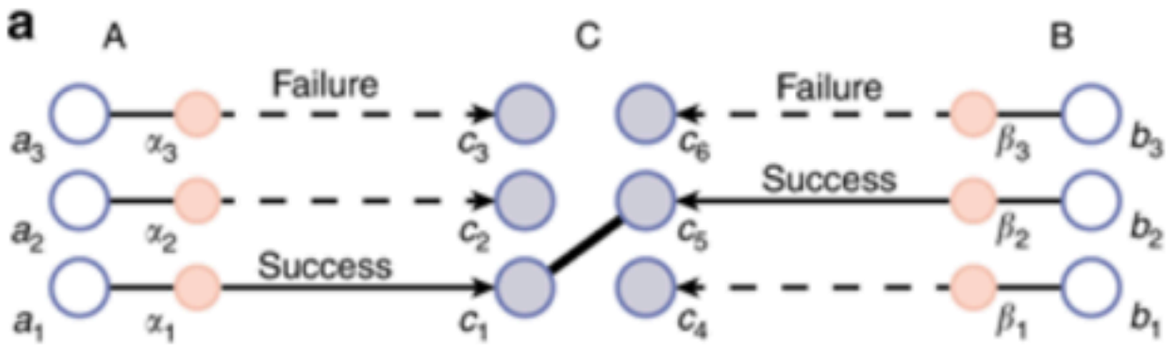


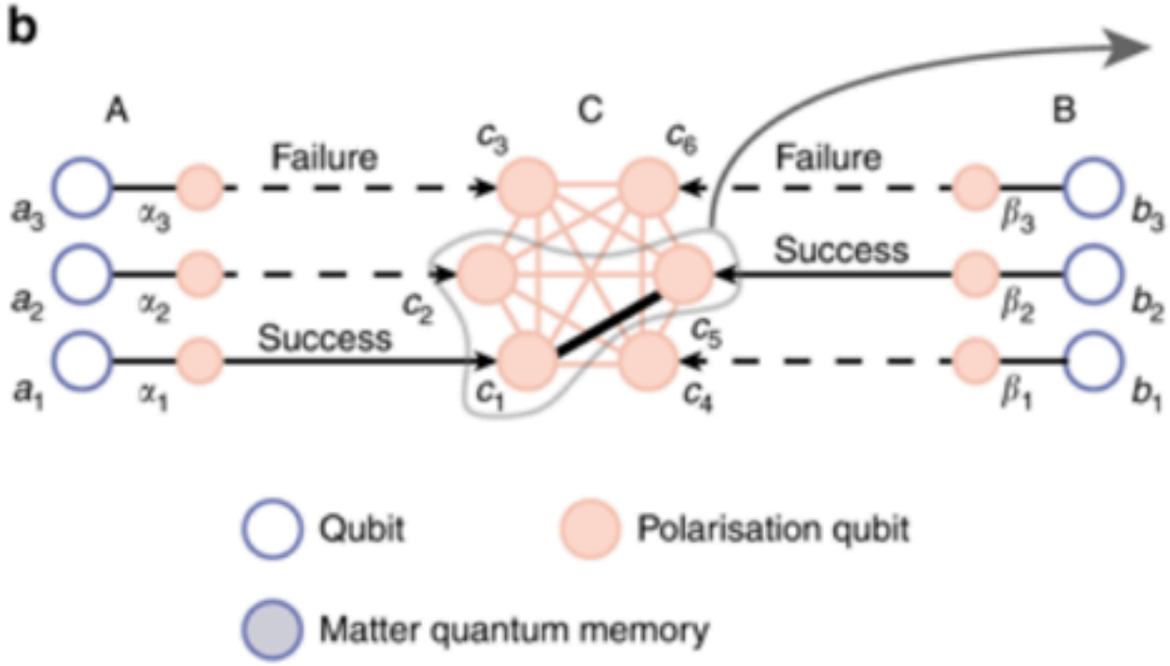
(2) Statistics of the success rate of entanglement purification gives good estimation for the fidelity of Bell pairs.

(1) Local check works in entanglement swapping for routing.

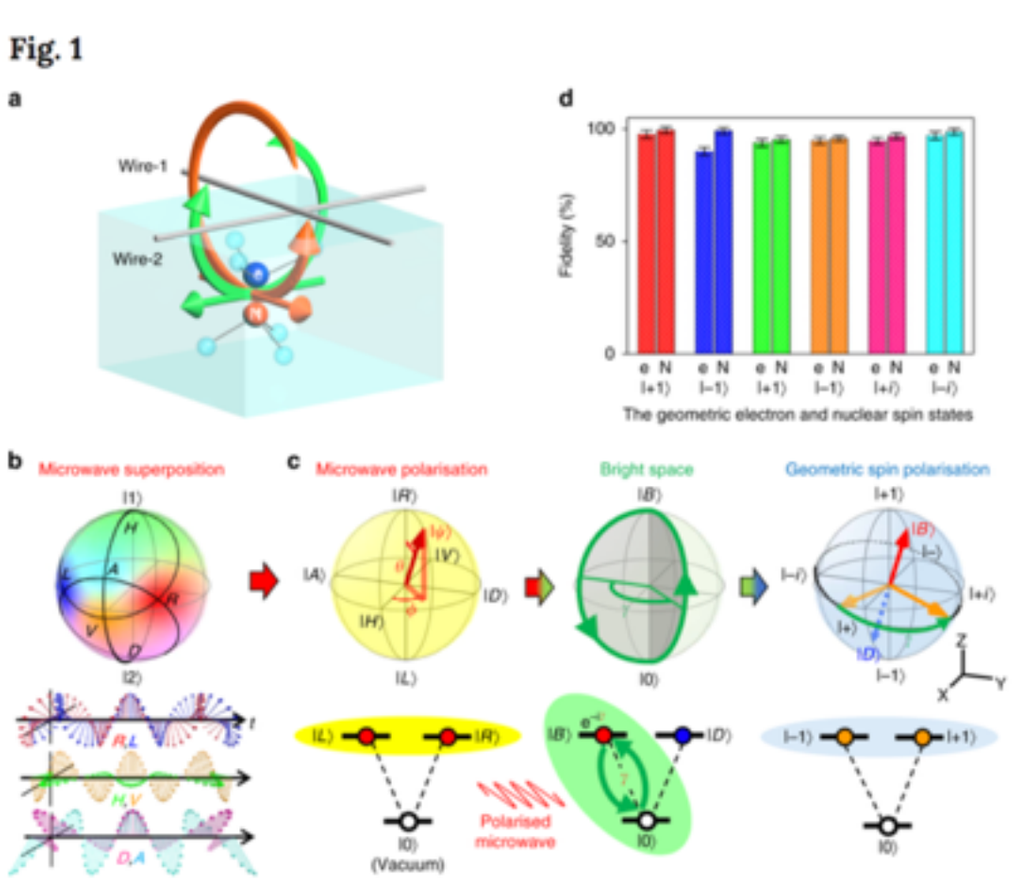
Health check via classical messaging is enough for quantum ping

Recent experiments in Japan





https://resou.osaka-u.ac.jp/en/research/2019/20190128_1
https://www.nature.com/articles/s41467-018-08099-5



https://www.nature.com/articles/s41467-018-05664-w