Quantum Networks for Open Science Workshop

Sponsored by the U.S. Department of Energy

Office of Advanced Scientific Computing Research

Rockville, Maryland

September 25–26, 2018

Position Papers

Call for Position Papers: Quantum Networks

Important Dates

- August 22, 2018: Position paper submission deadline
- August 27, 2018: Contact authors will be notified of selection for workshop
- September 25–26, 2018: Workshop dates

Workshop URL: https://www.orau.gov/quantumnetworks2018
Submission URL: https://easychair.org/conferences/?conf=qnos2018

Motivation

On behalf of the Advanced Scientific Computing Research (ASCR) program in the Department of Energy (DOE) Office of Science, a workshop on Quantum Networks (QNet) is being organized to support the emerging distributed quantum information sciences activities. ASCR has a long history of providing leadership in high performance computing. This leadership has led, not only to some of the most powerful high-performance computing systems, but also to state-of-the-art high-performance networks that have brought major contributions to modern Internet technologies. As computing moves into the post-Moore's Law era, this symbiotic relationship must now evolve to include not only quantum computing, but also quantum networking capabilities: the inevitable existence of quantum computing capabilities at multiple sites establishes the need for a quantum network; and such a network will enable scientific advances that will not be possible with isolated quantum processors. Just as quantum computing will be a transformative capability for post-Moore's Law computing, quantum networks will be critical to realizing the full potential of quantum information sciences. The ASCR focus for this workshop is end-to-end quantum communications networks.

The purpose of the QNet workshop is to more clearly define the challenges that must be addressed in order to develop and deploy large-scale quantum networks, enabling ecosystems capable of supporting diverse distributed quantum information sciences activities in an open science environment. The scope of the workshop is to go beyond current point-to-point quantum links and quantum key distribution (QKD) systems. It is envisioned that the workshop discussions and findings will cover a broad spectrum of end-to-end quantum communications networks, and sub-systems ranging from quantum interconnects, to Quantum Local Area Networks (Q-LANs), Quantum Metropolitan Networks (Q-MANs), and Quantum Wide Area Networks (Q-WANs).

We encourage participation from a wide range of institutions including, but not limited to, universities, industries, and DOE National Laboratories. The workshop will feature a variety of plenary talks and multiple break-out sessions, with every invitee expected to participate actively in discussions of potential research directions. The workshop participants will produce a report that will define basic multidisciplinary needs and research opportunities in related fields of computer science and quantum physics in order to lay the foundation for scalable quantum networks for open science that will be seamlessly integrated with the current Internet.

Invitation

We invite community input to this new effort in the form of two-page position papers that identify and discuss key challenges encountered in the development and deployment of QNet infrastructures described above. In addition to providing an avenue for identifying workshop participants, the position papers will be used to shape the workshop agenda, identify panelists, and contribute to the workshop report. The organizing committee has identified three technical areas described below to guide the development of the position papers; however, position papers relevant to the subject matter but not covered in these three technical areas are also welcome. Position papers should not describe the authors' current or planned research, nor should they recommend solutions or narrowly focused research topics. Rather, they should aim to improve the community's shared understanding of the problem space and to help stimulate discussion.

- **QNet-enabled Science Applications and Workflows:** The focus of position papers on this theme should be on motivating drivers for quantum networks; specifically, potential science applications and new scientific workflows that will be enabled by high-performance quantum networks. Some examples may include, but are not limited to, distributed quantum entanglement-based applications and scalable QKD systems for the open science environment.

- **QNet—Beyond Point-to-Point Links:** The emphasis of this theme is on critical hardware and software subsystems, architectures and protocols, topologies, and components needed to develop and deploy

scalable high-performance quantum networks described above. They include, but are not limited to, the following: a) basic quantum devices (buffers, quantum memories, detectors, frequency converters, etc.); b) quantum network components (quantum nodes, switches, quantum repeaters, quantum photon sources, etc.); c) long-distance quantum channels (optical channel characterization, optical impairments, digital and quantum channels coexistence, dense wavelength-division multiplexing/coarse wavelength-division multiplexing (DWDM/CWDM) channelization, etc.); and d) quantum and optical gates and processors for manipulating optical signals and quantum information in the network.

- **QNet Control, Modeling, and Management**: The ability to control, predict, manage, and characterize network behaviors and performance was critical to the successful evolution of classical networks. These features are also critical to the design and development of large-scale high-performance quantum networks; specifically, in the following contexts: 1) How to groom the quantum traffic from multiple quantum sources? 2) Will quantum networks need end-to-end signaling mechanisms as do transparent optical networks? 3) What are the robust metrics to model the performance of quantum networks? 4) What are the potential cybersecurity vulnerabilities of the quantum nodes?

Out of Scope Topics: The following related topics, although critical to the overall global reach of quantum networks, are adequately addressed elsewhere (other government agencies and the private sector) and as such will be considered out of scope for this workshop: a) wireless quantum network technologies, b) satellite-based quantum technologies, and c) quantum computing materials development.

References:

1. R. J. Runser *et al.*, "Progress Toward Quantum Communications Networks: Opportunities and Challenges." https://www.spiedigitallibrary.org/conference-proceedings-of-spie/6476/64760I/Progress-toward-quantum-communications-networks-opportunities-and-challenges/10.1117/12.708669.full?SSO=1

2. H. J. Kimble, "The quantum internet," Nature **453,** 1023 (2008). https://arxiv.org/pdf/0806.4195.pdf

3. European Quantum Technologies Roadmap, pp. 41-71. https://qt.eu/app/uploads/2018/04/QT-Roadmap-2016.pdf

4. Japan's National Institute of Information and Communications Technology Roadmap. https://www.nict.go.jp/en/quantum/roadmap.html

5. Workshop for Quantum Repeaters and Networks, Duke University. http://wqrn.pratt.duke.edu/index.html

Submission Guidelines

The position papers should describe fundamental open problems and research directions in the multidisciplinary areas of computer science and quantum physics that are associated with the development and deployment of large-scale quantum networks for open science. Specifically, the applicants can assess the responsiveness of their position papers by answering the following questions:

- Key Open Problems: Which open problem(s) related to quantum networks does this paper address?

- Research Direction: What are some promising research directions in computer science and quantum physics that address these open problems?

- State of the Art: What recent networking innovations could potentially be leveraged in the identified research directions?

The answers to the above questions should be followed by an assessment of the potential research directions based on the following dimensions:

- Maturity: Are there existing research directions in computer science and quantum physics that address the identified challenge(s) and that show promise for furthering the development of quantum networks for open science? What are the indicators that a given method or approach is addressing the identified challenges? If there are no existing methods or research approaches to meet the challenges, then in what ways can new insight into the problem space be gained?

- Timeliness: Why now? What breakthrough/change indicates that rapid progress is possible now?

- Uniqueness: Are the identified open problems unique to computer science and quantum physics? What makes it so?

- Novelty: To what extent are the new approaches/methods/research directions unique to quantum networks research? Are these approaches being addressed by other research programs? By the private sector? How are they different from the existing approaches or solutions? Why should they be of interest to ASCR's networking research effort?

Position Papers Format

Each position paper must be no more than two pages (with no smaller than one inch margins and 12 point font) in length, including figures and references. The paper may include any number of authors, but must provide contact information for a single author, who could represent the position paper at the workshop. There is

no limit to the number of position papers that an individual or group can submit. Authors are strongly encouraged to follow the technical content structure outlined above. Submit position papers in PDF format at the URL listed above.

Selection

Submissions will be reviewed by the Organizing Committee. Authors of selected submissions will be invited to participate in the workshop, which will be held on September 25–26, 2018, in Rockville, MD. Authors are not expected to have a history of funding by the ASCR's quantum networks research effort. Authors of selected position papers will be invited to participate in the workshop based on the overall quality of the position paper(s) and an expectation that their active participation in the workshop will stimulate constructive discussion by the workshop participants and contribute to an informative report. Unique positions that are well presented and emphasize potentially transformative research directions will be given preference.