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# 第14部

# 分散型量子計算のネットワーク応用技術（概要版）

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## 第１章　Abstract

The AQUA (Advancing Quantum Architecture) working group continued research activities advancing quantum computing and communication, especially quantum networking and distributed quantum computing systems. Our research contributes to planning for the long-term evolution of the computing and networking industries as Moore's Law comes to an end. In 2016, AQUA members published eight papers in journals and workshops on quantum error correction and quantum repeater networks.

## 第２章　Introduction

WIDE, through the AQUA working group, is well positioned to participate in and help guide the field in this exciting area, particularly as it moves from theoretical papers and small laboratory technology demonstrations toward actual systems.

This report first discusses recent work in WIDE on quantum networks, then quantum error correction and quantum architecture. This is followed by a summary of 2017's major publications.

## 第３章　Quantum Networks

A quantum repeater's work consists of three tasks: (1) generation of base-level entanglement with its nearest neighbors, using fiber or free space links; (2) managing errors (via error detection or error correction); and (3) coupling the single-hop entanglement into longer-distance entanglement, e.g. via a method known as entanglement swapping. Experimental and theoretical physicists have worked hard on the physical layer mechanisms for generating entanglement, and theorists have studied means of managing errors while building entanglement along a chain of repeaters, but little energy has been invested so far in designing *networks* of quantum repeaters.

Building on the work done over the last ten years, the work done by AQUA in 2016 and early 2017 has completed our list of provisional technical proposals for almost every aspect of creating a true entanglement-based Quantum Internet above the physical layer.

## 第４章　Quantum Error Correction and Quantum Computer Architecture

In addition to the work on quantum networks, AQUA members have conducted research on error correction for quantum computers and quantum computer architecture. In our opinion, as well as the opinion of a number of others, the *surface code* represents the most attractive method, encoding a logical qubit in the parity of chains of qubits on a surface. AQUA members published four papers in this area this year, including a survey article in *IEEE Computer,* a design for a million-qubit quantum computer, and two important advances in engineering of the surface code.

## 第５章　Publications

AQUA members had seven journal papers published or accepted

for publication in 2016 and one peer-reviewed workshop paper, several international conference poster presentations, and three additional submissions. The published and accepted papers are:

1. Shota Nagayama, Austin G. Fowler, Dominic Horsman, Simon J. Devitt and Rodney Van Meter, "Surface Code Error Correction on a Defective Lattice," *New Journal of Physics*.

2. Shota Nagayama, Takahiko Satoh and Rodney Van Meter, "State Injection, Lattice Surgery and Dense Packing of the Defermation-Based Surface Code," *Physical Review A*, 2017.

3. Rodney Van Meter and Simon Devitt, "The Path to Scalable Distributed Quantum Computing," *IEEE Computer* 49(9), 31-42.

4. Takahiko Satoh, Kaori Ishizaki, Shota Nagayama and Rodney Van Meter, "Analysis of quantum network coding for realistic repeater networks," *Physical Review A* 93(3), 032302, 2016.

5. Shota Nagayama, Byung-Soo Choi, Simon Devitt, Shigeya Suzuki and Rodney Van Meter, "Interoperability in encoded quantum repeater networks," *Physical Review A* 93(4), 042338, 2016.

6. Simon J. Devitt, Andrew D. Greentree, Ashley M. Stephens and Rodney Van Meter, "High-speed quantum networking by ship," *Scientic Reports* 6, 36163, 2016.

7. Takafumi Oka and Takahiko Satoh and Rodney Van Meter, "A Classical Network Protocol to Support Distributed Quantum State Tomography," *Proc. Quantum Communications and Information Technology,* Dec. 2016.

8. Muhammad Ahsan, Rodney Van Meter and Jungsang Kim, "Designing a Million-Qubit Quantum Computer Using a Resource Performance Simulator," *J. Emerg. Technol. Comput. Syst.* 12(4), 39, 2016.

AQUA submitted three more papers on quantum repeater network engineering in January 2017:

1. Rodney Van Meter, Takahiko Satoh, Shota Nagayama, Takaaki Matsuo and Shigeya Suzuki, "Optimizing Timing of High-Success-Probability Quantum Repeaters," preprint arXiv:1701.04586.

2. Takahiko Satoh, Shota Nagayama, and Rodney Van Meter, "The Network Impact of Hijacking a Quantum Repeater," preprint arXiv:1701.04587.

3. M. Amin Taherkhani, Keivan Navi, Rodney Van Meter, "Resource-aware architecture for implementation of quantum aided Byzantine agreement on quantum repeater networks," preprint arXiv:1701.04588.