Classical Engineering of Quantum Networks and Distributed Quantum Architectures

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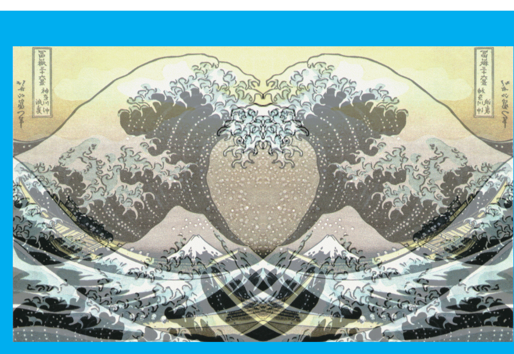
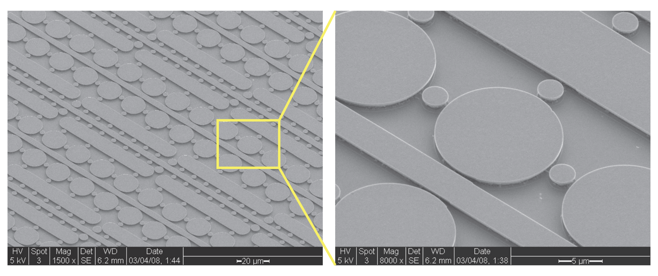


Devices



Test device created only to explore fabrication issues. rdv et al., IJQI (2010)

With Stanford University, we are designing large-scale quantum computing chips using quantum dots designed to hold a single electron. Defects are an issue [6]!

Workloads

We are focusing primarily on efficient implementations of existing, important algorithms and subroutines:

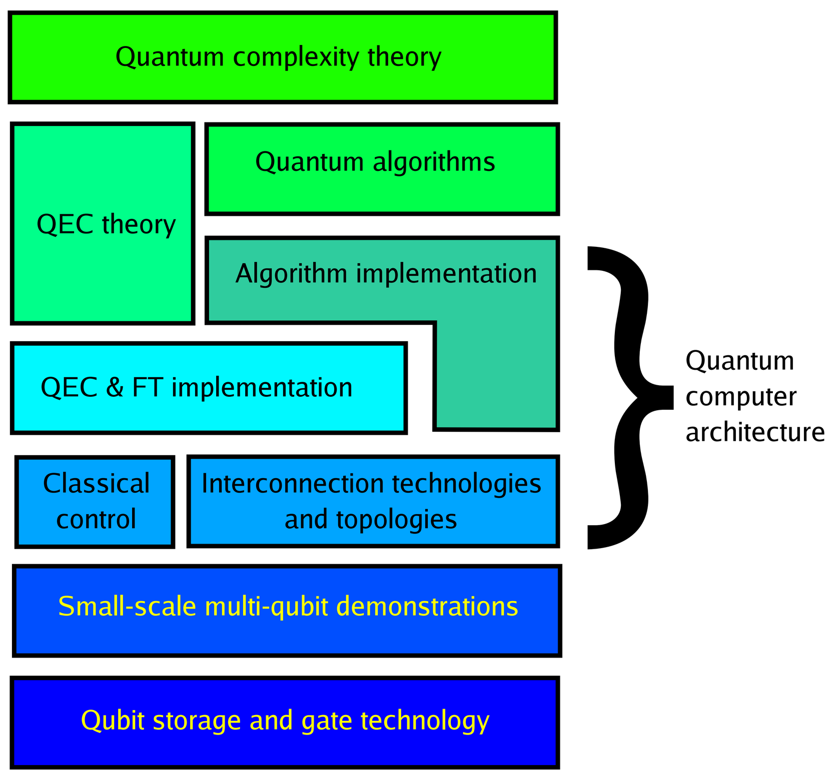
▲ quantum arithmetic (for Shor' s algorithm and others); and

▲ quantum simulation algorithms.

Our implementations are orders of magnitude better than prior ones.

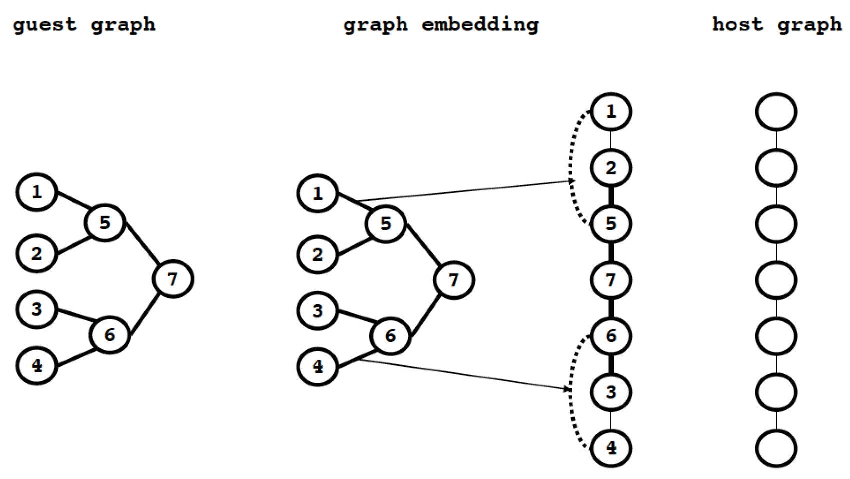
We are also interested in new quantum algorithms.

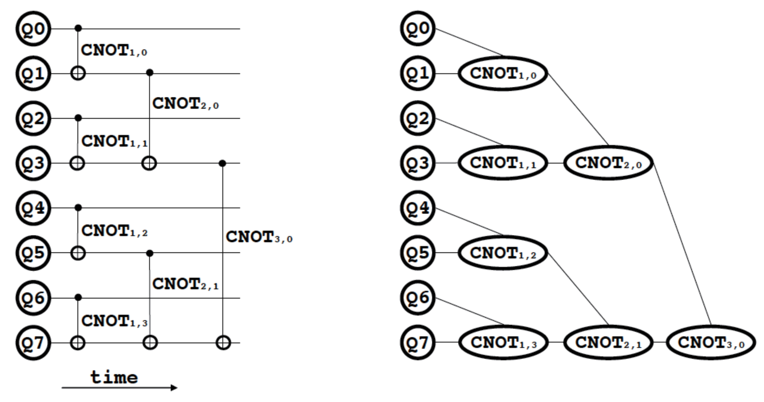
Architectural Principles

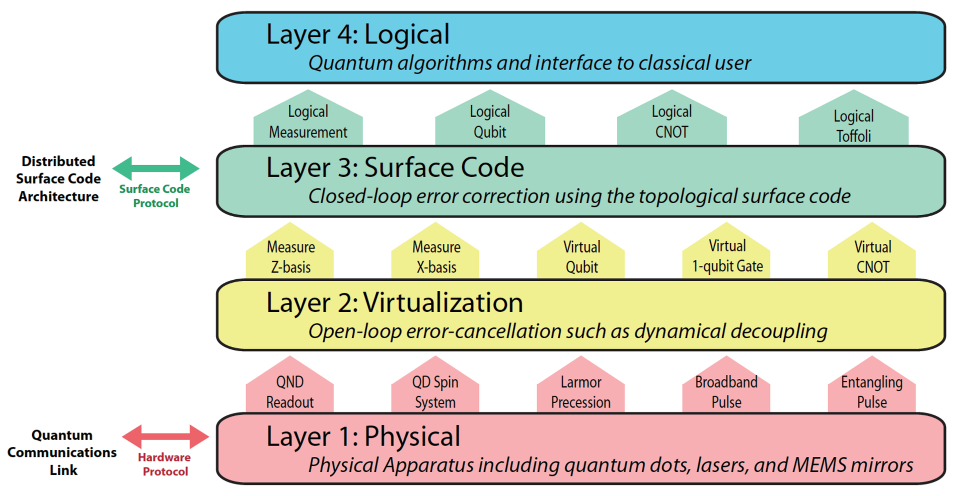


Tools

We are developing both algorithms and software tools for efficient compilers and system design, including visualization. One example is graph embedding, for mapping an algorithm to an architecture.

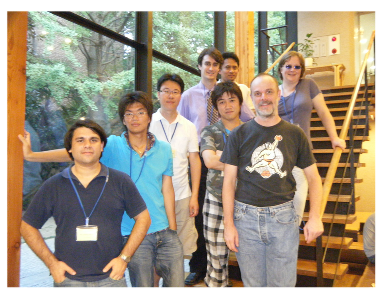






Jones et al., in preparation

Our focus is on determining which classical network and system engineering principles apply in the quantum world, and which do not.



Issues in Quantum Network Design

This work is part of a project addressing various issues in quantum network and distributed systems design:

▲ topology and scheduling of cooperatively scheduled, homogeneous networks (system area networks, or SANs) [1,2];

▲ path selection in heterogeneous networks (metro-area and wide-area networks, MANs and WANs) [3];

▲ layered protocol design and classical optimization of repeaters [3]; and

▲ applications for distributed quantum information, including Quantum Key Distribution for Internet encryption (IPsec) [4].

References

[1] R. Van Meter, T.D. Ladd, A.G. Fowler and Y. Yamamoto, IJQI 8(1-2), 295-323, 2010.

[2] R. Van Meter, W.J. Munro, K. Nemoto, K.M. Itoh, J. Emerging Tech. in Comp. Sys. 3(4), 2008.

[3] T. Satoh, R. Van Meter, et al., in preparation; L. Aparicio et al., in preparation.

[4] R. Van Meter, T.D. Ladd, W.J. Munro, K. Nemoto, IEEE/ACM Trans. on Networking 17(3), 2009.

[5] S. Nagayama, R. Van Meter, "IKE for IPsec with QKD," Internet Draft -00, Oct. 2009, expired April 22, 2010.

[6] S. Nagayama et al., in preparation.

[7] Bacon & van Dam, CACM, Feb. 2010.

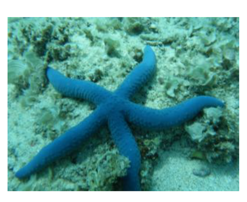
Why Work on Quantum Computing?

Moore' s Law tells us that transistors keep getting smaller -- but that process must end soon! The key part of a transistor is only about 60 atoms long; in fifteen years, it will be only 12. To maintain the pace of technological advances, we must learn to control quantum effects. We can either **use** them, or **suppress** them. If we use them, quantum algorithms may accelerate solving some problems:

▲ **factoring:** The most famous quantum algorithm, Shor' s, makes factoring large numbers a polynomial problem;

▲ **quantum simulation:** Feynman originated the idea of quantum computers as simulators for other quantum systems;

▲ algorithms for solving linear equations, finding hidden subgroups, graph theory, game theory and more [7].

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