# The quantum simulator for FX700/A64FX cluster systems

Fujitsu Limited

# Why is quantum simulator required?

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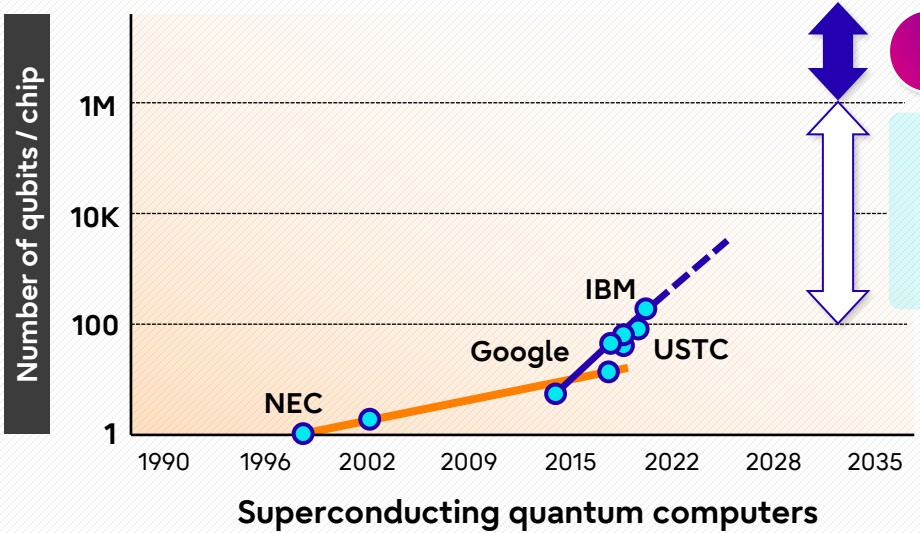
- **Simulator is essential for theoretical quantum algorithm R&D**
  - 100qubit NISQ* machines have appeared, but fault-torelance hasn't been developed yet
  - NISQ contains a lot of noise, so it's difficult to use it for theoretical R&D e.g., quantum algorithm




**Fault-torelant quantum computer**

**NISQ* computer**

**Expected to beneficial for limited applications**

*NISQ : Noisy Intermediate-Scale Quantum

> a full-fledged quantum computer, with 1000 logical qubits, might end up containing many millions of physical qubits
>
> Adrian Cho, Science, July 9, 2020

# The world's fastest quantum simulator

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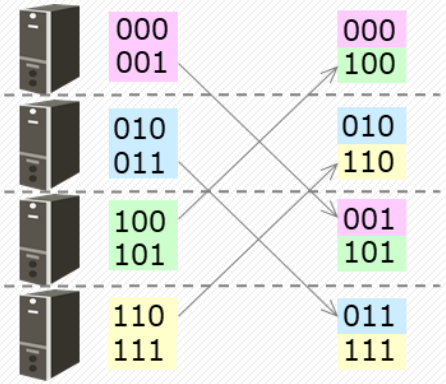
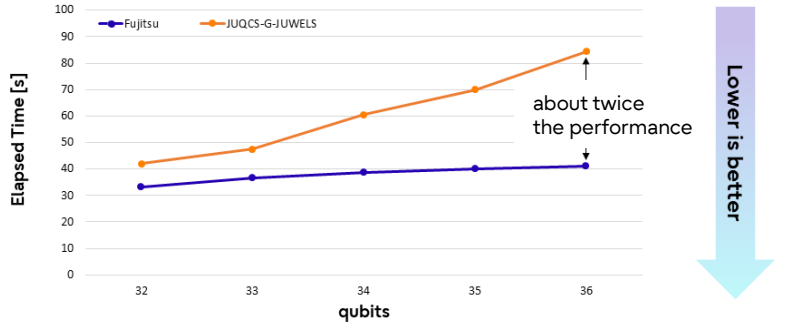
- **Developed 36 qubit quantum computer simulator system, taking advantage of performance by A64FX for Fugaku**
  - Achieved the world's fastest processing speed with **approximately twice the performance** of other major quantum simulators
  - By using this technology, for example, the calculation that took a whole day could be completed only at night, which made it possible to dramatically improve the efficiency of the R & D cycle

## Fused-swap technology for quantum simulation

- ✓ The communication was reduced by swapping the data on the parallel computer
- ✓ Optimized by the sequence of gates in quantum circuit




Achieved up to twice the speed up compared to the JUQCS (GPU simulator)

# Feature of Fujitsu's quantum simulator

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- **Accelerate the performance of quantum simulator by Fujitsu's large-scale parallel computing technologies**

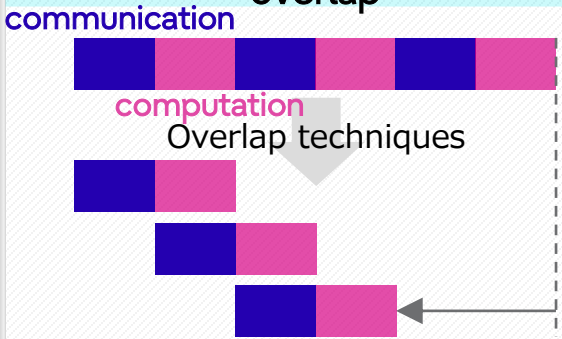
## Technology 1

### A64FX


Maximized memory bandwidth for quantum simulation workload

## Technology 2

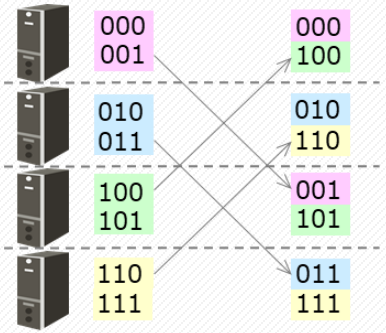
### communication and computation overlap




Boosted the performance by communication and computation overlap techniques

## Technology 3

### Fused-swap




Reduced communication by data swap in distributed memory optimized by sequence of quantum gates

**Developed 36-qubit simulator by FX700 (64 nodes)**

# 1-qubit gate operation performance

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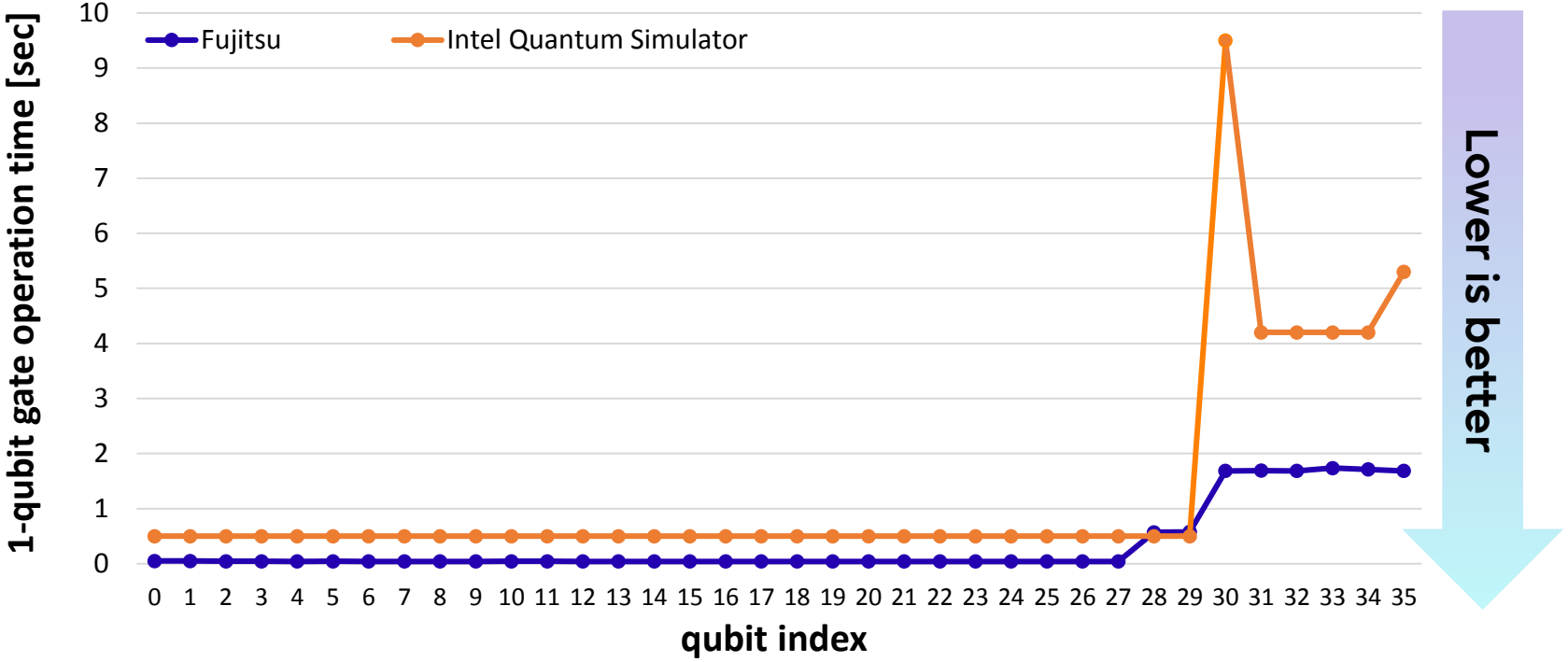


**10 times faster (qubit 0-27) / 3 times faster (qubit 31-34)**

# Hadamard gate benchmark

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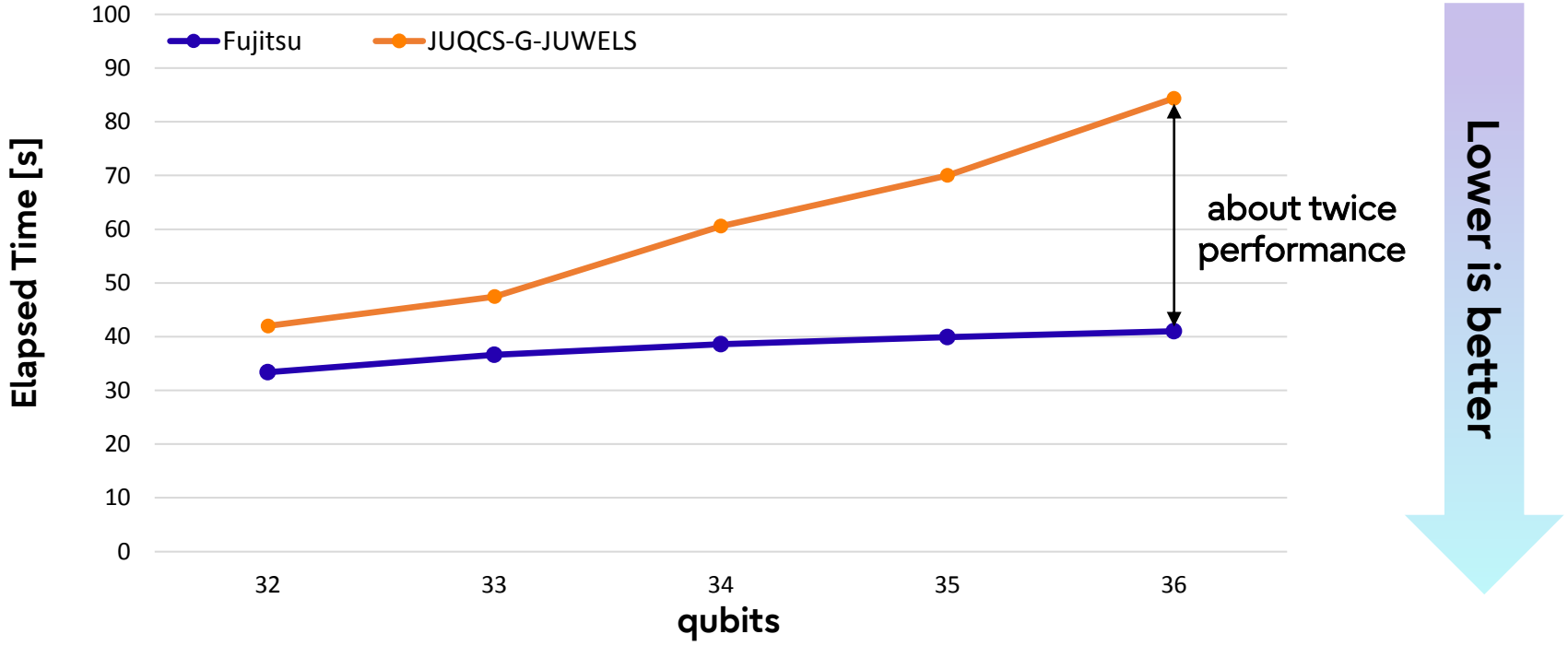


**Achieved up to twice the speed up**

# Thank you

Please see “mpiQulacs: A Distributed Quantum Computer Simulator for A64FX-based Cluster Systems”, https://arxiv.org/abs/2203.16044