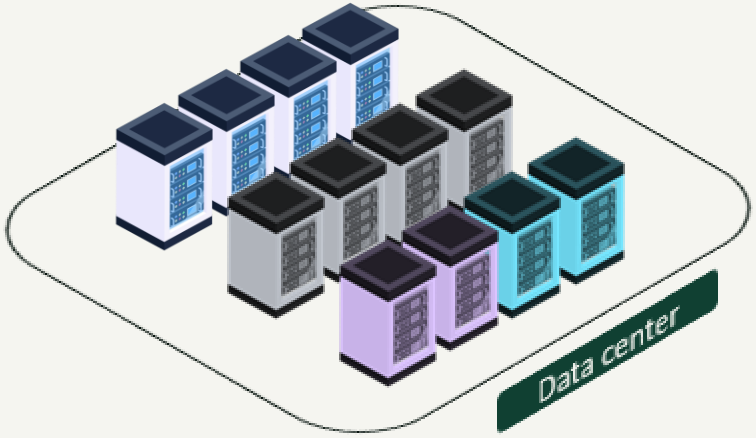
Compilation strategies for Quantum Data Centers

Mathys Rennela, Quantum Software Architect

Quantum computers are here to boost data centers

Data centers are at the core of the AI revolution and contribute to massive value creation.[1]



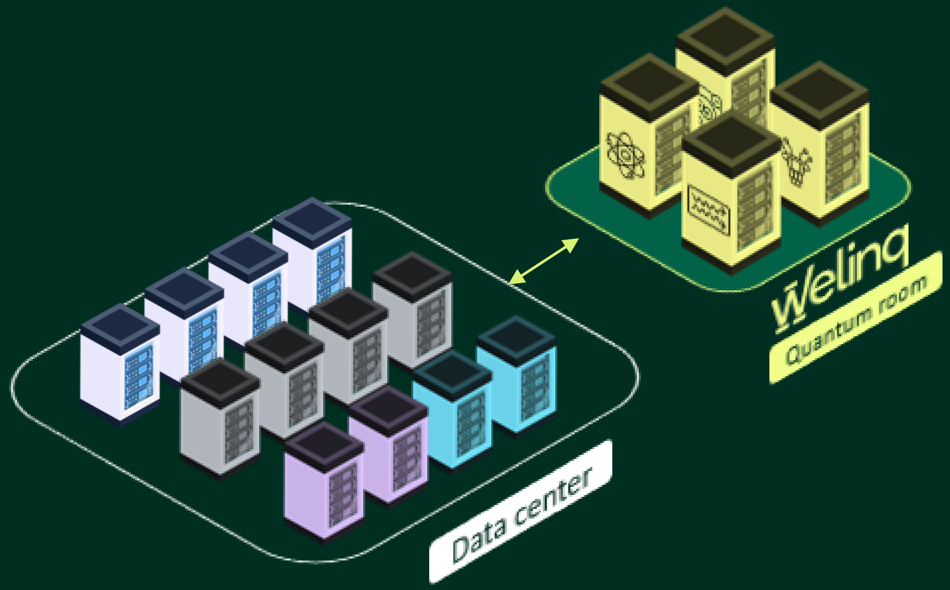
$3000B+

Global market value (20% CAGR)

$500B+[2]

Investment in Data Centers for 2025

The next step is to supercharge them with quantum computers.



"QPUs will be added to GPUs or CPUs to extend classical computing, to do things it otherwise can't"[3]

Jensen Huang, CEO NVIDIA

1 . Bärtschi, Andreas, et al. "Potential Applications of Quantum Computing at Los Alamos National Laboratory." arXiv:2406.06625 (2024).

2 . https://www.enr.com/articles/60211-openai-oracle-softbank-vow-to-invest-500b-for-more-us-data-centers

3. https://www.hpcwire.com/2025/03/25/gtc-quantum-day-jensens-mea-culpa-nvidias-growing-quantum-bet/

Quantum computers alone are not enough

Quantum computers are already here…

Number of quantum computers deployed world-wide according to *Global Quantum Intelligence*

…but now, they need to be deployed in clusters

Welinq's full-stack solution for quantum networking

Welinq

- Use Cases
- Distributed QEC
- Quantum Compiler
- Optical Quantum Network
- Quantum Memory Buffer
- Qubit-Photon Interfaces
- QPUs

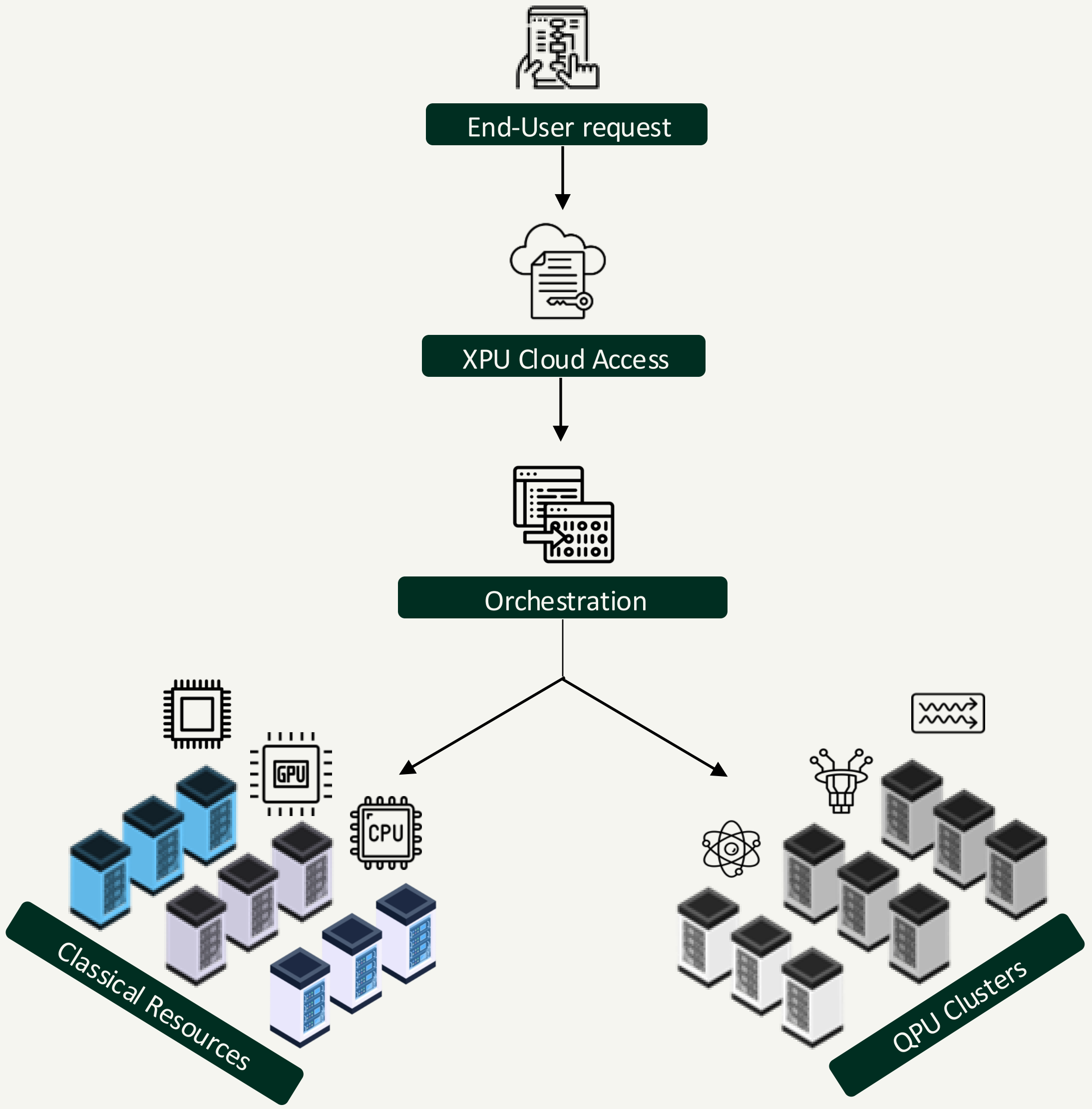
AQADOC, world's largest initiative dedicated to distributed use-cases

araQne, state-of-art compiler for modular QC

QDrive, world's most performant quantum memory

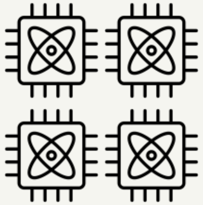
Highly-performant qubit-photon interfaces, integrated in our partners' QPUs

Quantum Data Center Workflow

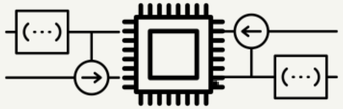


Large quantum computers as interconnected quantum processing units

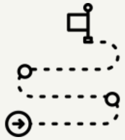
Algorithm splitting



Error-corrected QPU-to-QPU interconnection

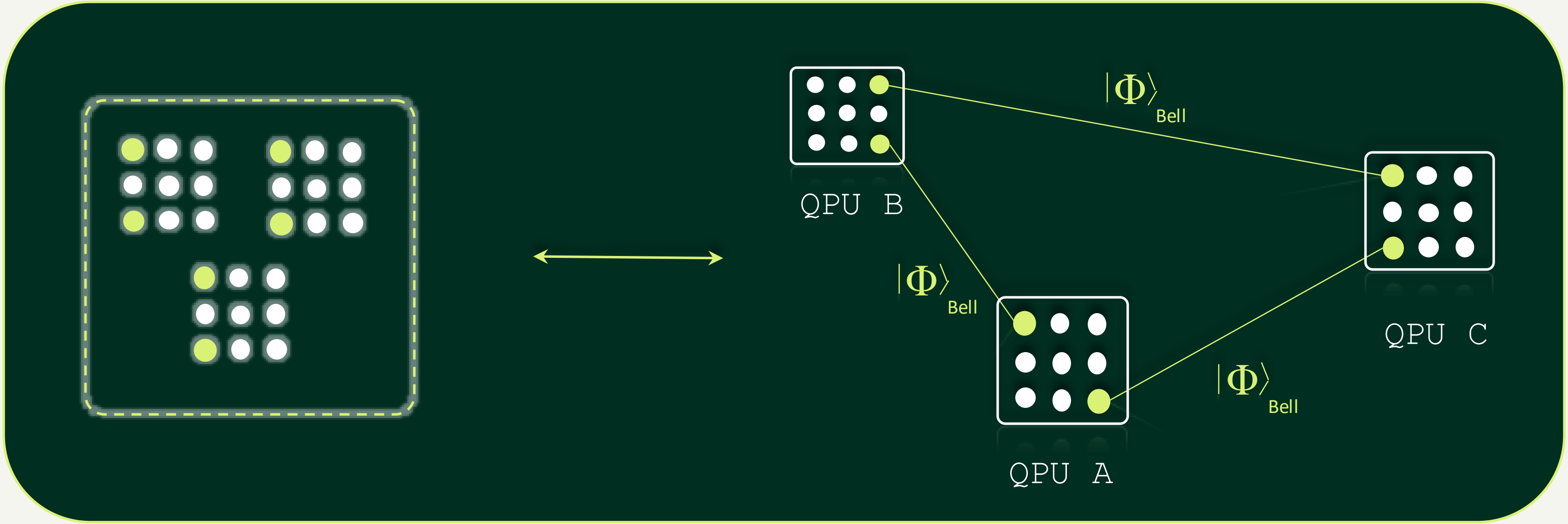


Virtual Implementation



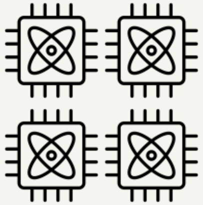
Network routing

Job scheduling



Benchmarking interconnected quantum processing units

Algorithm splitting



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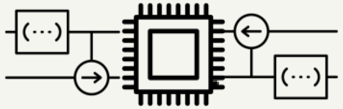

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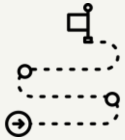


Network routing

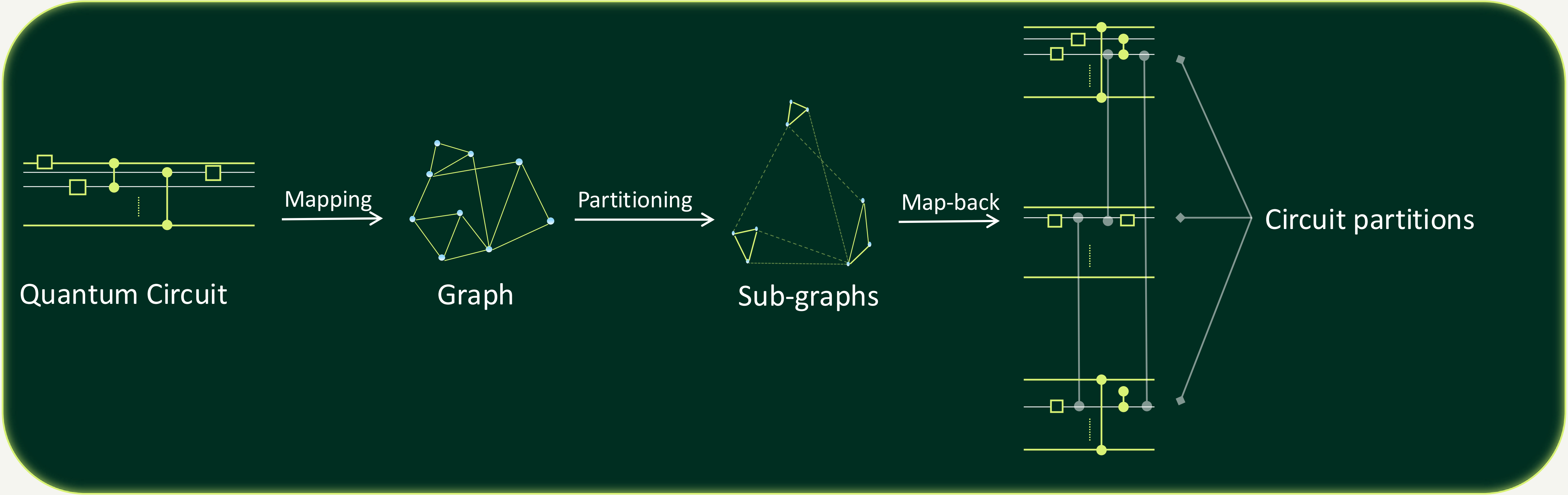
Job scheduling

<u>Network performance:</u> network latency, total fidelity / error rate.

<u>Computing performance:</u> total runtime, circuit depth, classical processing power needed.

<u>Resource use:</u> **entanglement resource**, entanglement swapping, communication protocols.

How to distribute quantum circuits

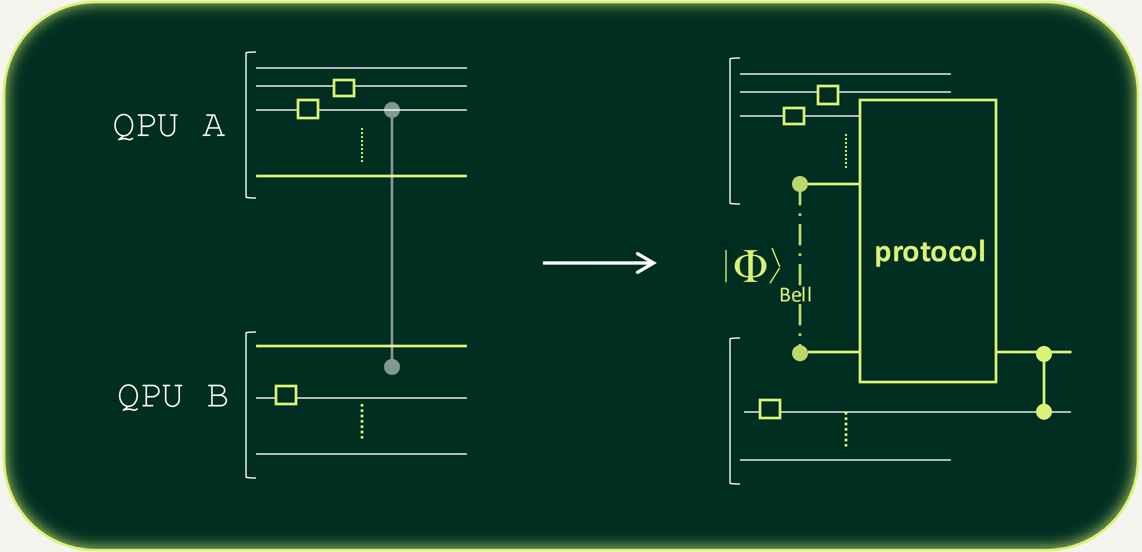


Graph-based approaches reduce the problem of distributing quantum circuits across a quantum network to a graph partitioning problem.

Benchmarking distributed quantum computing

Quantum links are quantum communication protocols, which consume entangled pairs.
They implement quantum gates acting on qubits located on different QPUs.

However, entanglement is a scarce resource.



The goal is to distribute a quantum circuit across a quantum network while minimizing the use of entanglement resources (distribution cost).

Benchmarking the distribution cost

araQne is Welinq's compiler for quantum data centers.
It distributes efficiently *monolithic* quantum circuits across a network of *interconnected* quantum processing units.

Benchmarking suites:

- QASMBench 1.4
- Randomly generated circuits (CNOT + single-qubit rotations)

Circuit (qubits)	Greedy algorithm	Baseline method
Adder (28)	7	9
Adder (64, 118)	7	10
BV (70, 140)	1	1
Cat (35)	1	1
DNN (33)	19	27
DNN (51)	29	42
GHZ (40)	1	1
Ising (34)	1	1
KNN (41)	1	1
Multiplier (45)	162	238
Multiplier (75)	380	568
Multiplier (350)	6397	10954
Multiplier (400)	8319	13492
QFT (29)	14	210
QFT (63)	36	739
QFT (160, 320)	40	820
QRAM (20)	18	33
QuGAN (39)	24	34
QuGAN (71)	38	55
QuGAN (111)	58	85
QuGAN (395)	196	292
QV (32)	600	600
QV (100)	6492	6492
Swap Test (25)	12	18
Swap Test (41)	20	30
Swap Test (83)	40	60
W-State (76, 118)	2	2
Square root (45)	3418	4419

THANK YOU