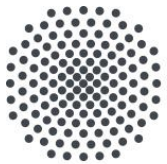
Qunicorn: A Middleware for the Unified Execution Across Heterogeneous Quantum Cloud Offerings



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Motivation

- Quantum computing promises speed-up
- Quantum cloud offerings enable access to quantum computers
  - IBMQ
  - AWS Braket
  - …
- Offerings differ in their features:
  - Pricing
  - Access methods
  - Support for advanced functionalities, e.g., error mitigation
  - …

First Research Question

- Selection of a suitable quantum cloud offering is difficult
- Identification of the key features of each offering required
- Research question:

> What are relevant features of quantum cloud offerings, and how do the various quantum cloud offerings differ regarding the support of these features?

Evaluation Criteria (1/2)

- **Access models**
  - Queue
  - Prioritized queue
  - Exclusive time slot
- **Batch Processing**
- **Error Handling**
  - Error Mitigation
  - Error Correction
- **Hybrid Runtime**

Evaluation Criteria (2/2)

- **Integrated Development Environment**
  - Composer
  - Online Code Editor
- **Pricing Models**
  - Time-based
  - Circuit-based
  - Subscription-based
- **Trial Access**

Results of the Evaluation

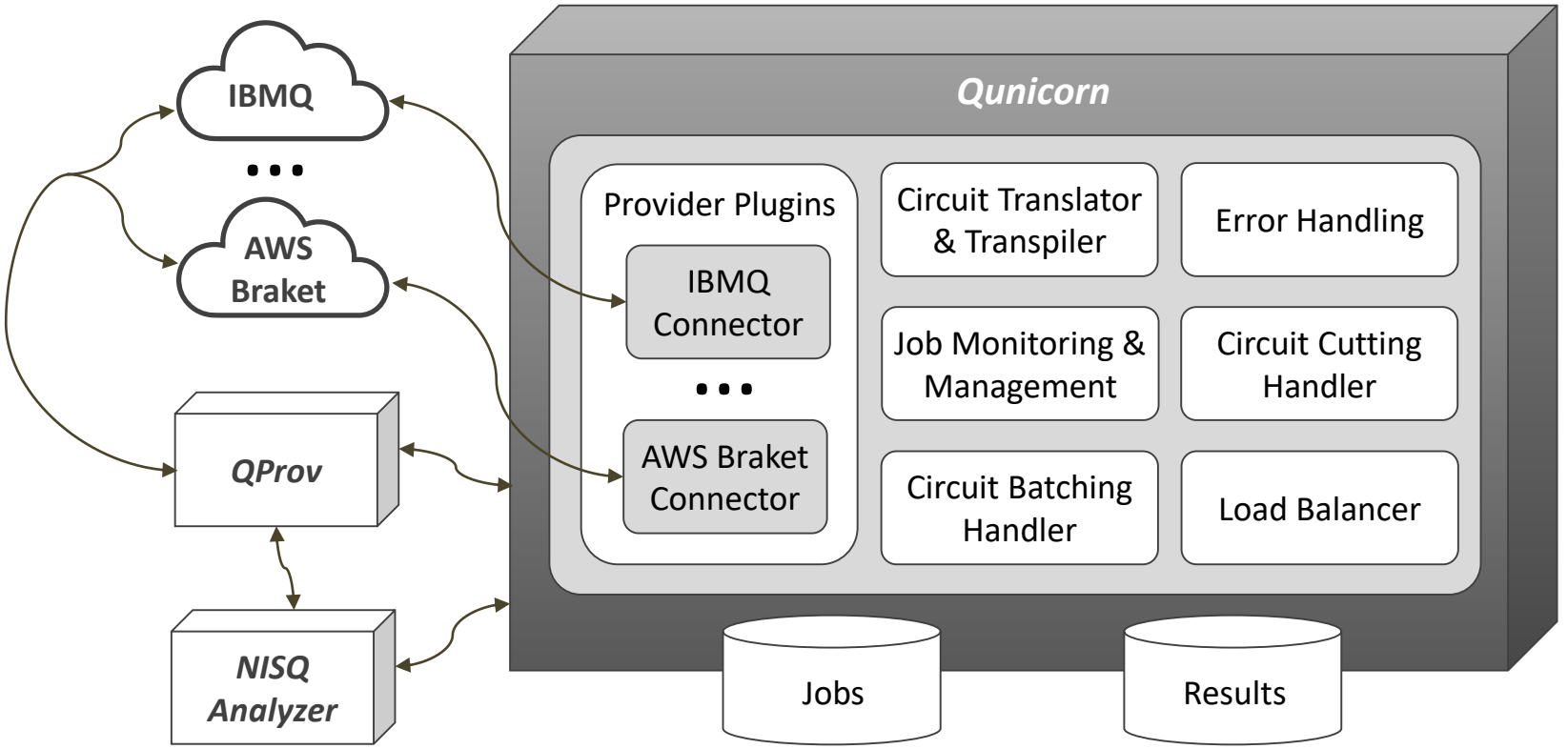
	Criteria	Alice & Bob	AWS Braket	Azure Quantum	IBMQ	IonQ	qBraid	Quandela	Quantum Inspire
Access Methods	Queue	✓	✓	✓	✓	✓	✓	✓	✓
	Priority Queue	✗	✓	✓	✓	✗	✗	✓	✗
	Exclusive Time Slot	✓	✓	✗	✓	✓	✗	✓	✗
Error Handling	Error Mitigation	✗	✓	✓	✓	✓	✓	✓	✗
	Error Correction	✗	✗	✗	✗	✗	✗	✗	✗
Pricing Models	Time-based	✓	✓	✓	✓	✗	✗	✗	✗
	Circuit-based	✗	✓	✓	✗	✓	✓	✓	✗
	Subscription-based	✗	✗	✓	✗	✗	✗	✓	✗

Switching Between Different Quantum Cloud Offerings

- The most suitable quantum cloud offering might change over time
- Switching between offerings is difficult:
  - Different programming languages and SDKs
  - Translation of quantum applications is very complex
- Research question:

> How to execute quantum circuits independently of the heterogeneity of quantum cloud offerings regarding their supported quantum circuit and result formats?

Unification Middleware for Quantum Cloud Offerings



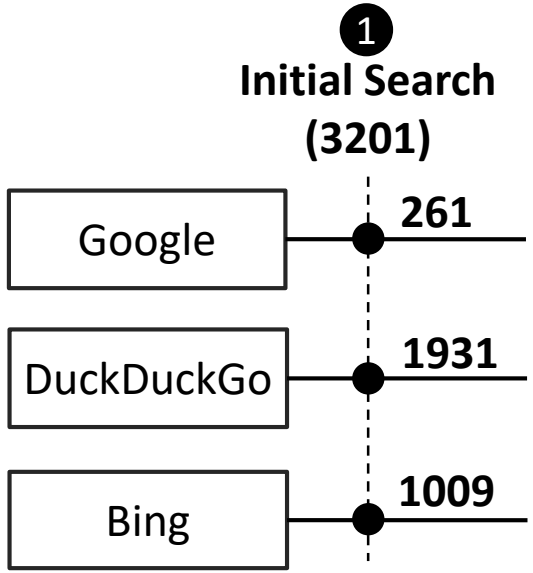
Conclusion & Future Work

- Quantum circuits can be executed via heterogeneous quantum cloud offering
- Selecting a suitable quantum cloud offering is difficult
- Qunicorn eases executing quantum circuits independently

- Future work:
  - Evaluation of the unification middleware in a user study
  - Integration of additional quantum cloud offerings

Thank you for your attention ☺

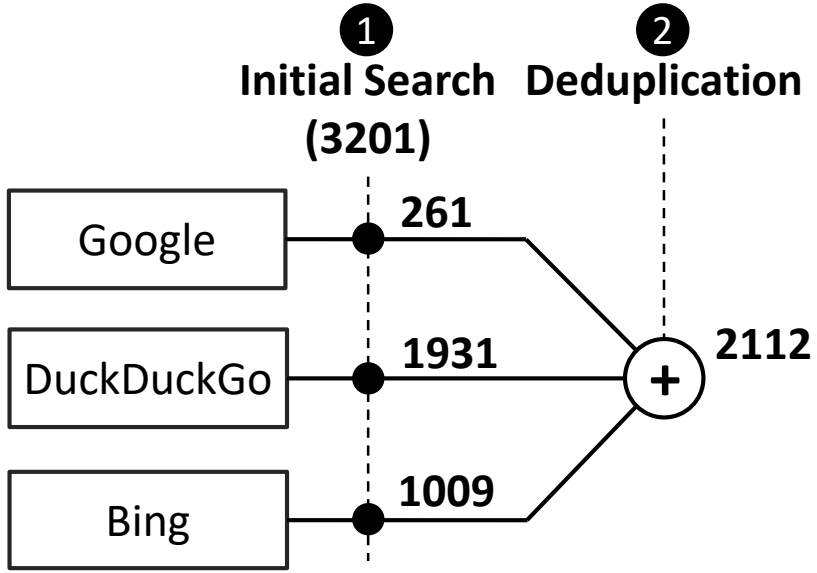
Gray Literature Review – Initial Search



- Web search using three search engines

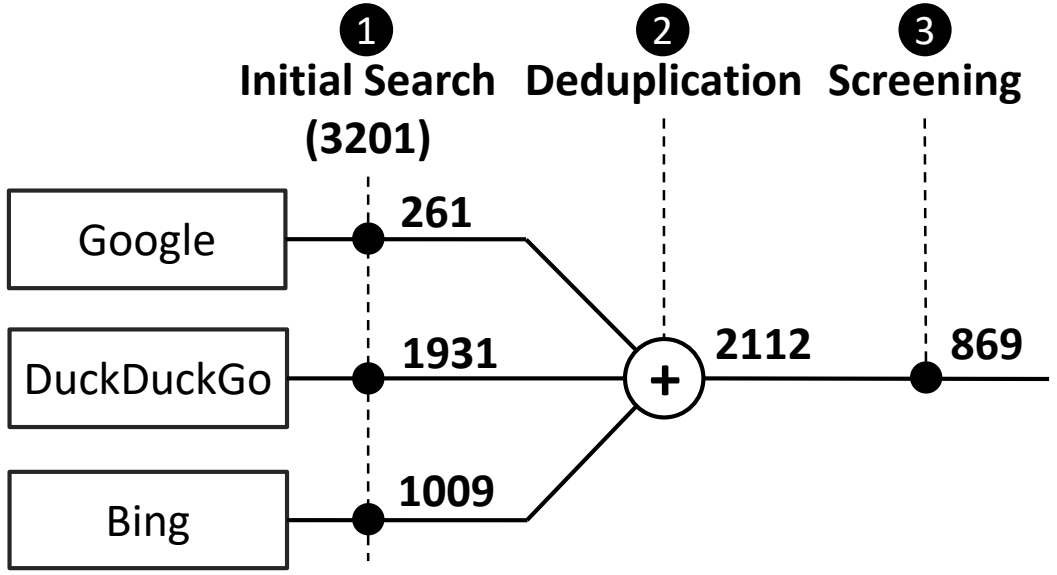
- Search term: quantum computing AND
  (cloud OR platform OR service OR offering OR company)

Gray Literature Review – Deducplication



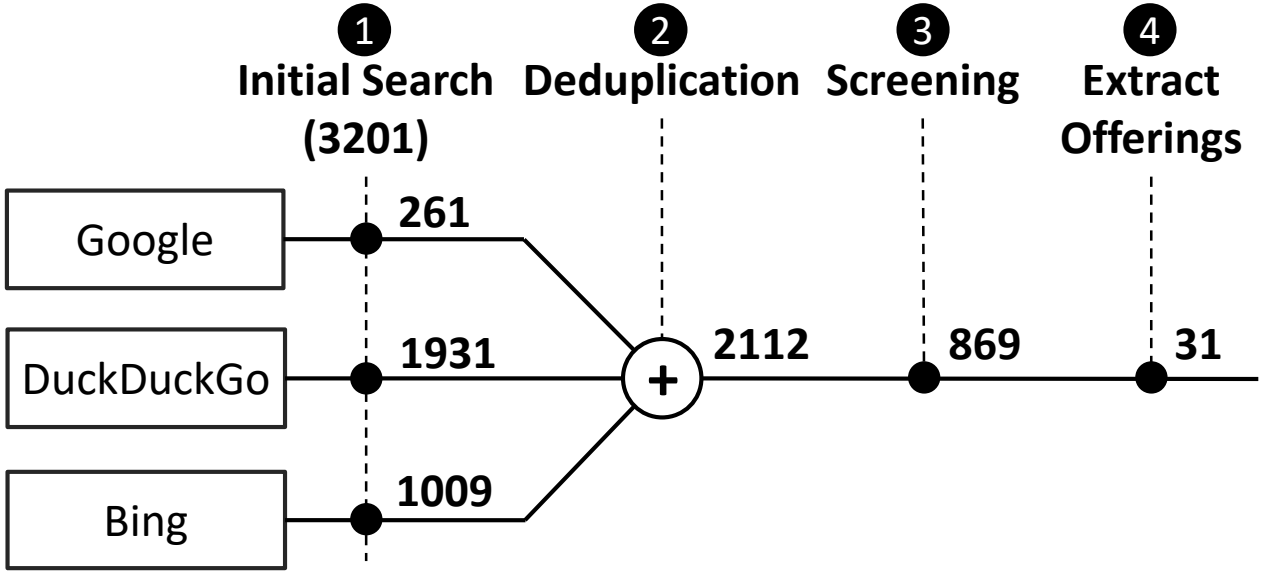
- Data sets from the engines are merged into a single data sets
- Entries with the same URL are removed

Gray Literature Review – Screening



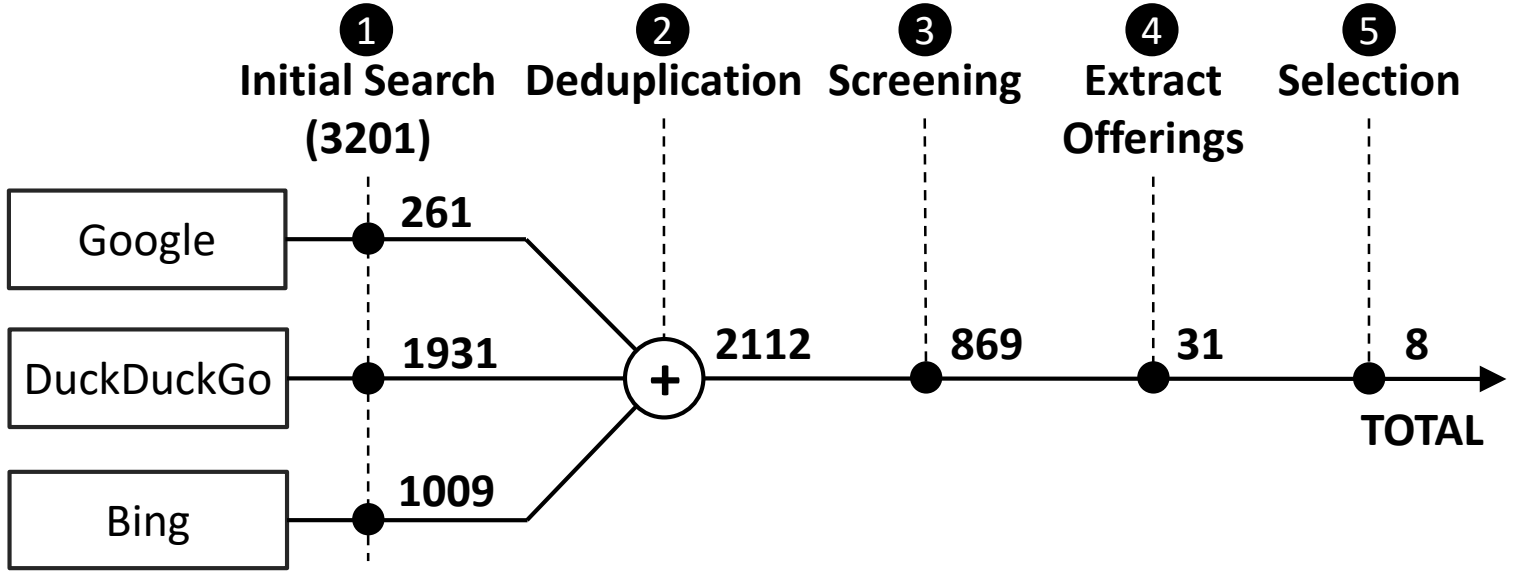
- Websites are scanned by two researchers to assess their relevance
- Removal of irrelevant websites:
  - Not in English
  - Academic papers or videos
  - …

Gray Literature Review – Extract Offerings



- In-depth analysis of the websites to extract quantum cloud offerings

Gray Literature Review – Selection



- Filtering based on inclusion and exclusion criteria:
  - ✓ Publicly available
  - ✓ Suitable documentation
  - × Provides only simulators or annealers
  - × Beta, early access, or pre-release version or research prototype