

Workload and Workflow Management in Quantum-Classical HPC

Shweta Salaria
IBM Research



Why Scripts Are Not Enough for QCSC Workflows?

Limitations of a typical script-based approach



Execution history is not systematically recorded

It becomes unclear which parameters were used and when jobs were executed.

Recovery from failures is difficult

A failure in the middle often requires restarting the entire workflow.

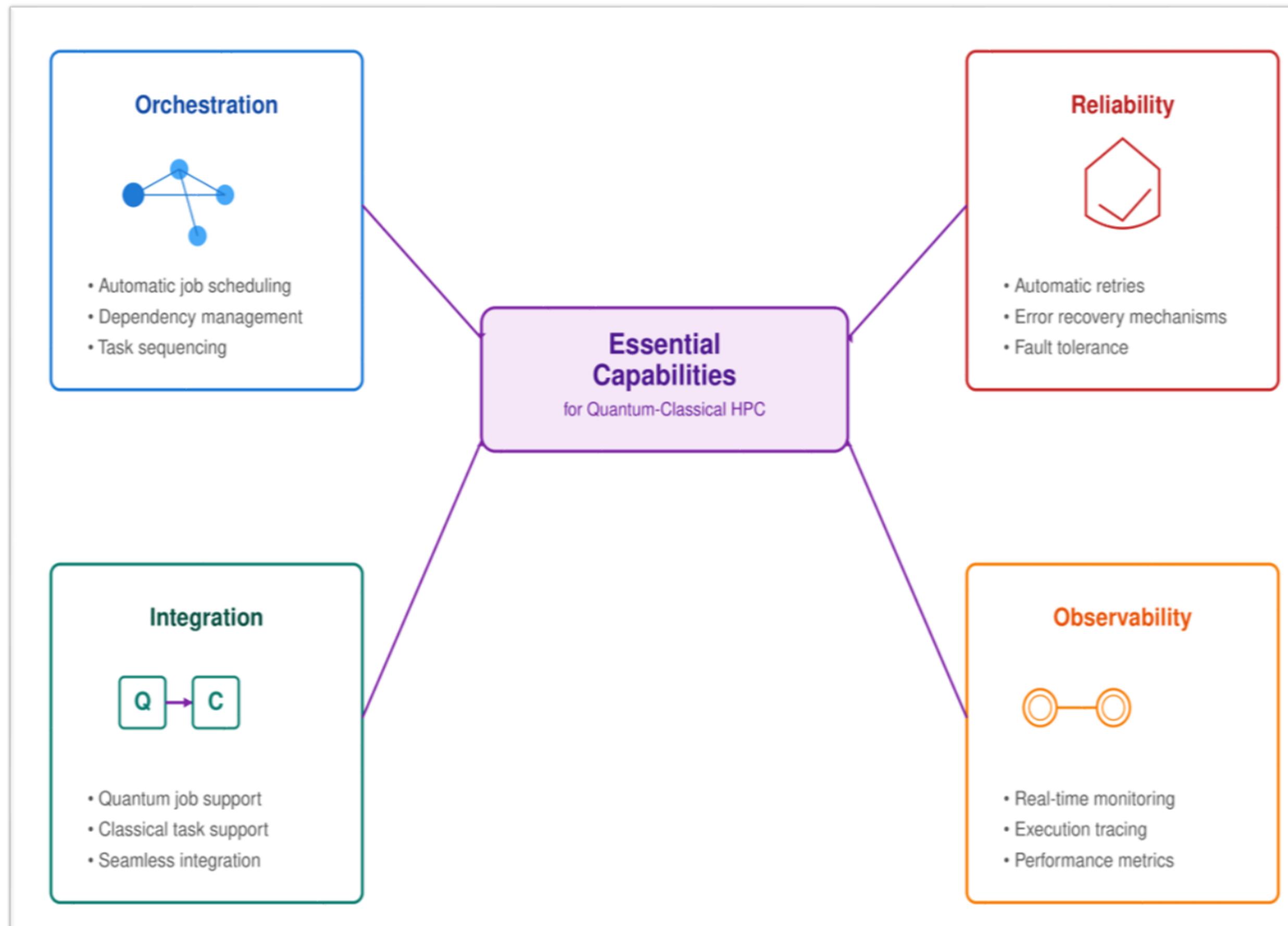
Quantum and classical steps are fragmented

Quantum executions, HPC jobs, and post-processing are managed separately.

Reproducibility and comparison are hard

It is difficult to trace why a particular result was obtained.

What Should a QCSC Orchestrator Deliver?



Explicit execution flow

The execution order and dependencies between steps are clearly defined and managed by the system.

Efficient recovery from failures

Only failed tasks need to be re-executed, avoiding unnecessary re-runs of expensive computations.

Unified quantum–classical workflows

Quantum executions and HPC jobs are handled within a single, coherent workflow

Reproducible experimental runs

Results are automatically linked with parameters and execution context, enabling reliable comparison.

Prefect: Python-based Workflow Orchestration Tool

- **Native Python**

Write workflows using pure Python code with decorators

- **Dynamic Execution**

Support for conditional logic, loops and runtime parameters

- **Observability**

Built-in UI for monitoring, logging and debugging workflows

- **Error Handling**

Automatic retries, failure notifications and recovery mechanisms

- **Deployment Options**

Run locally, on-premise or in Prefect Cloud

- **Scheduling**

Cron-based, interval and event-driven scheduling



```
import requests
from prefect import flow, task

@task(retries=3, retry_delay_seconds=5)
def fetch_data(url: str):
    return requests.get(url).json()

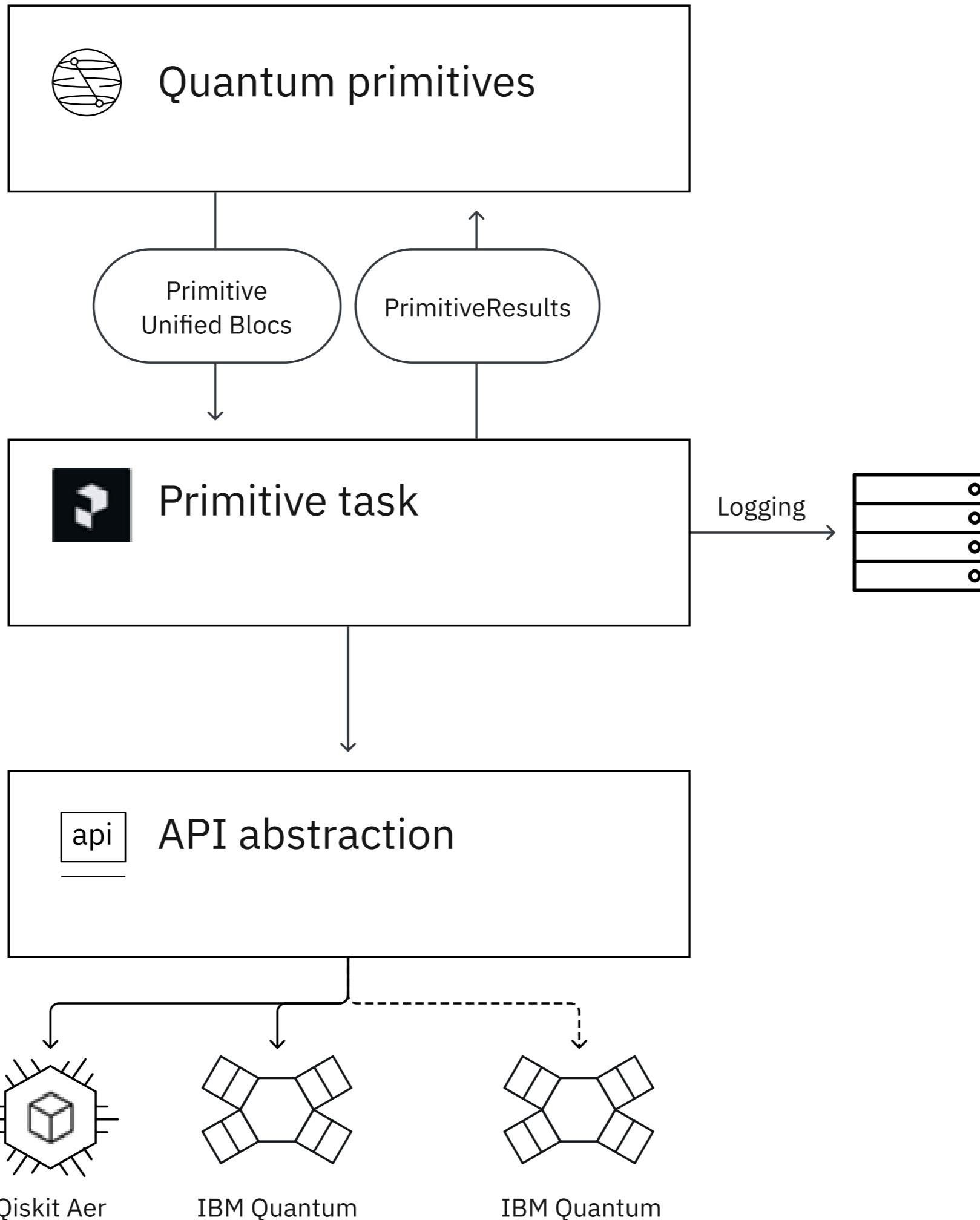
@flow(name="Data Ingestion Pipeline")
def my_workflow(api_url: str):
    # This looks like standard Python, but it's now orchestrated!
    data = fetch_data(api_url)
    print(f"Processed: {data}")

if __name__ == "__main__":
    my_workflow(api_url="https://api.example.com/data")
```

Prefect Supports Qiskit

Features:

- Qiskit primitive programming with workflow syntax
- Multiple vendor support on API abstraction
- Async execution support for parallel primitive execution
- Built-in repeat until success mechanism for backend error handling
- Result cache mechanism for identical inputs
- Artifact generation for job performance metadata

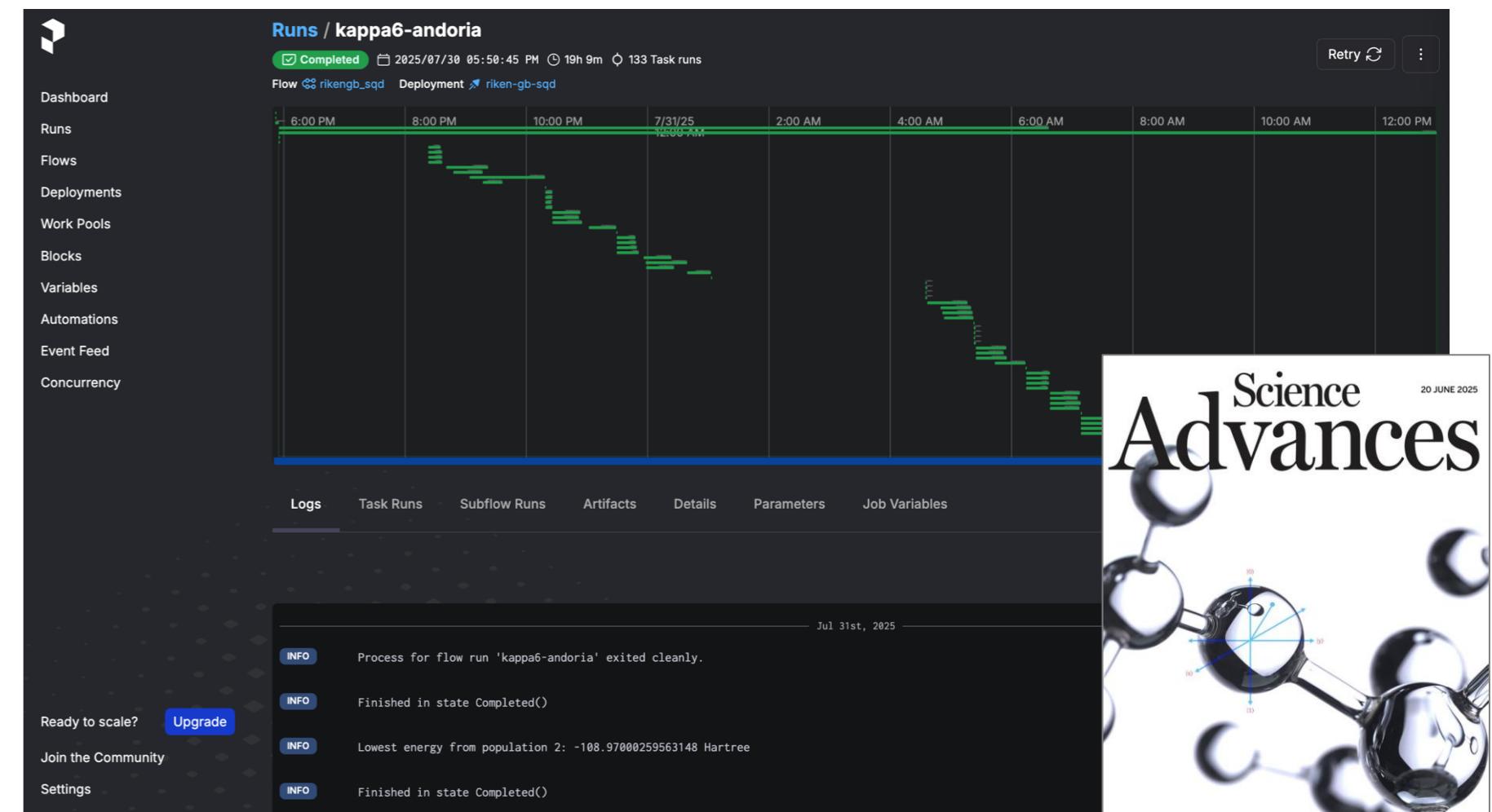


```
@flow
def sample_bell():
    logger = get_run_logger()

    # 1. Load QuantumRuntime from Prefect Server
    runtime = QuantumRuntime.load("default-runtime")
    options = Variable.get("sampler_options")

    # 2. Create ISA quantum circuit
    bell = QuantumCircuit(2)
    bell.h(0)
    bell.cx(0, 1)
    bell.measure_all()
    isa_circ = transpile_task(
        circuit=bell,
        target=runtime.get_target(),
    )

    # 3. Execute workflow sampler
    result = runtime.sampler([isa_circ], options=options)
    logger.info(result[0].data.meas.get_counts())
```



QCSC Workflow with Prefect

Program: BitCount (Quantum + MPI)

- Sample bitstrings using a quantum computer
- Count how many times each bitstring appears using MPI

```
1 import asyncio
2 import json
3 from prefect import flow
4 from prefect.artifacts import create_table_artifact
5 from prefect.variables import Variable
6 from prefect_qiskit import QuantumRuntime
7 from qiskit import QuantumCircuit
8 from qiskit.transpiler import generate_preset_pass_manager
9 from get_counts_integration import BitCounter
10 from qiskit.primitives.containers.sampler_pub import SamplerPub
11 from qiskit import qasm3
12 from get_task_runner import TaskRunner
13 from qiskit_ibm_runtime.utils import RuntimeEncoder
14 from qiskit_ibm_runtime.utils.result_decoder import ResultDecoder
15
16 BITLEN = 10
17
18 @flow(name="slurm_tutorial")
19 async def main():
20     # Load configurations
21     runtime = await QuantumRuntime.load("ibm-runner")
22     counter = await BitCounter.load("slurm-tutorial")
23     options = await Variable.get("slurm-tutorial")
24     taskrunner = await TaskRunner.load("slurm-tutorial")
25
26     # Create a PUB payload
27     target = await runtime.get_target()
28     qc_ghz = QuantumCircuit(BITLEN)
29     qc_ghz.h(0)
30     qc_ghz.cx(0, range(1, BITLEN))
31     qc_ghz.measure_active()
32
33     pm = generate_preset_pass_manager(
34         optimization_level=3,
35         target=target,
36         seed_transpiler=123,
37     )
38     isa = pm.run(qc_ghz)
39     pub_like = (isa,) # Create a Primitive Unified Bloc
40
41     # Extract shots
42     shots = options.get("shots", 100000) # default to 100000 if not set
43
44     dict_pubs = []
45
46     # Create input.json for task_runner
47     coerced_pub = SamplerPub.coerce(pub_like, shots=shots)
48
49     # Generate OpenQASM3 string which can be consumed by IBM Quantum APIs
50     qasm3_str = qasm3.dumps(
51         coerced_pub.circuit,
52         disable_constants=True,
53         allow_aliasing=True,
54         experimental=qasm3.ExperimentalFeatures.SWITCH_CASE_V1,
55     )
56
57     if len(coerced_pub.circuit.parameters) == 0:
58         if coerced_pub.shots:
59             dict_pubs.append((qasm3_str, None, coerced_pub.shots))
60         else:
61             dict_pubs.append((qasm3_str))
62     else:
63         param_array = coerced_pub.parameter_values.as_array()
64         coerced_pub.circuit.parameters
65             .tolist()
66
67         if coerced_pub.shots:
68             dict_pubs.append((qasm3_str, param_array, coerced_pub.shots))
69         else:
70             dict_pubs.append((qasm3_str, param_array))
71
72     # Create SamplerV2 input
73     input_json = {
74         "pubs": dict_pubs,
75         "shots": shots,
76         "options": options,
77         "version": 2,
78         "support_qiskit": True,
79     }
80     print("Here is the input json:", input_json)
81
82     taskrunner_json = {"parameters": input_json, "program_id": "sampler"}
83     print("Here is the taskrunner json:", taskrunner_json)
84
85     filename = "/mnt/data/salaria/slurm_tutorial/input.json"
86     with open(filename, "w", encoding="utf-8") as primitive_input_file:
87         json.dump(taskrunner_json, primitive_input_file, cls=RuntimeEncoder, indent=2)
88
89     # Quantum execution
90     result = await taskrunner.run()
91
92     # Read output
93     with open('/mnt/data/salaria/slurm_tutorial/output.json', 'r') as f:
94         results = ResultDecoder.decode(f.read())
95
96     # MPI execution
97     bitstrings = results[0].data.meas.get_bitstrings()
98     counts = await counter.get(bitstrings)
99
100
101    # Save in Prefect artifacts
102    await create_table_artifact(
103        table=[list(counts.keys()), list(counts.values())],
104        key="sampler-count-dict",
105    )
106
107 if __name__ == "__main__":
108     asyncio.run(main())
109
```

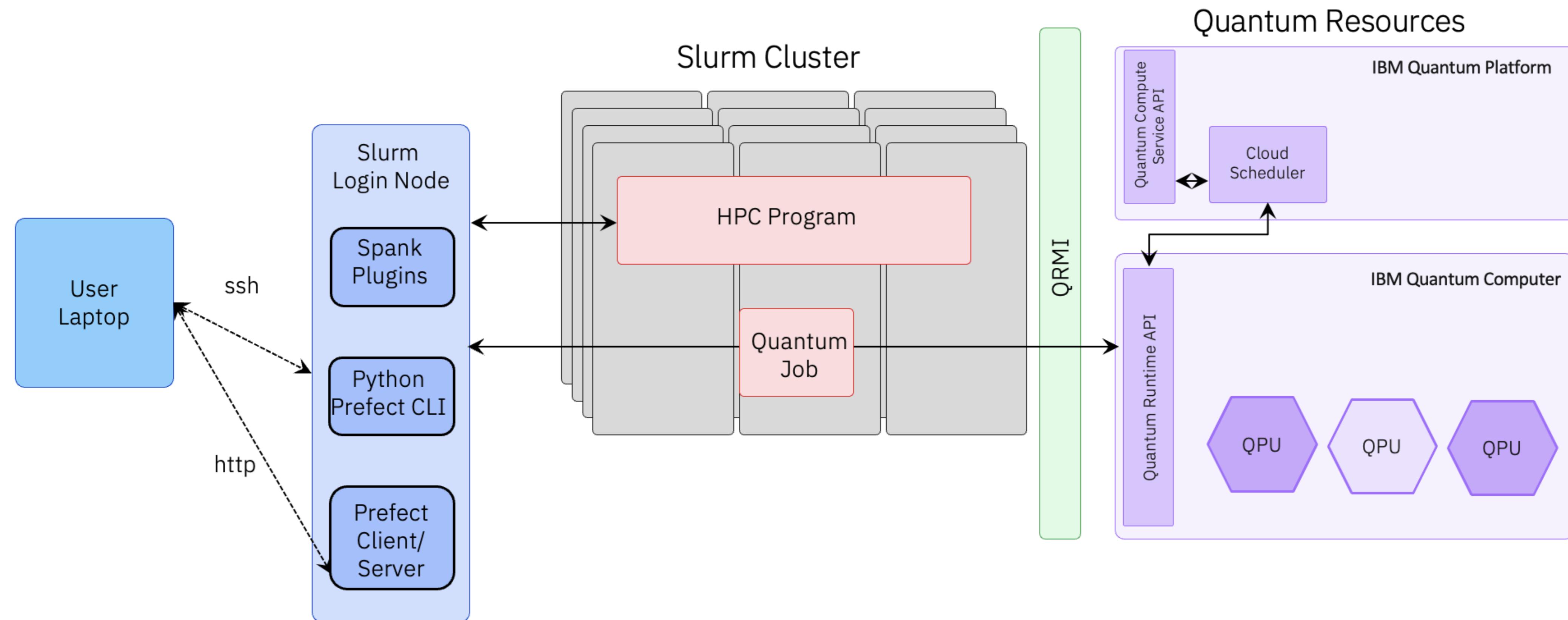
Create QCSC workflow: Quantum + MPI

Program: BitCount (Quantum + MPI)

- Sample bitstrings using a quantum computer
- Count how many times each bitstring appears using MPI

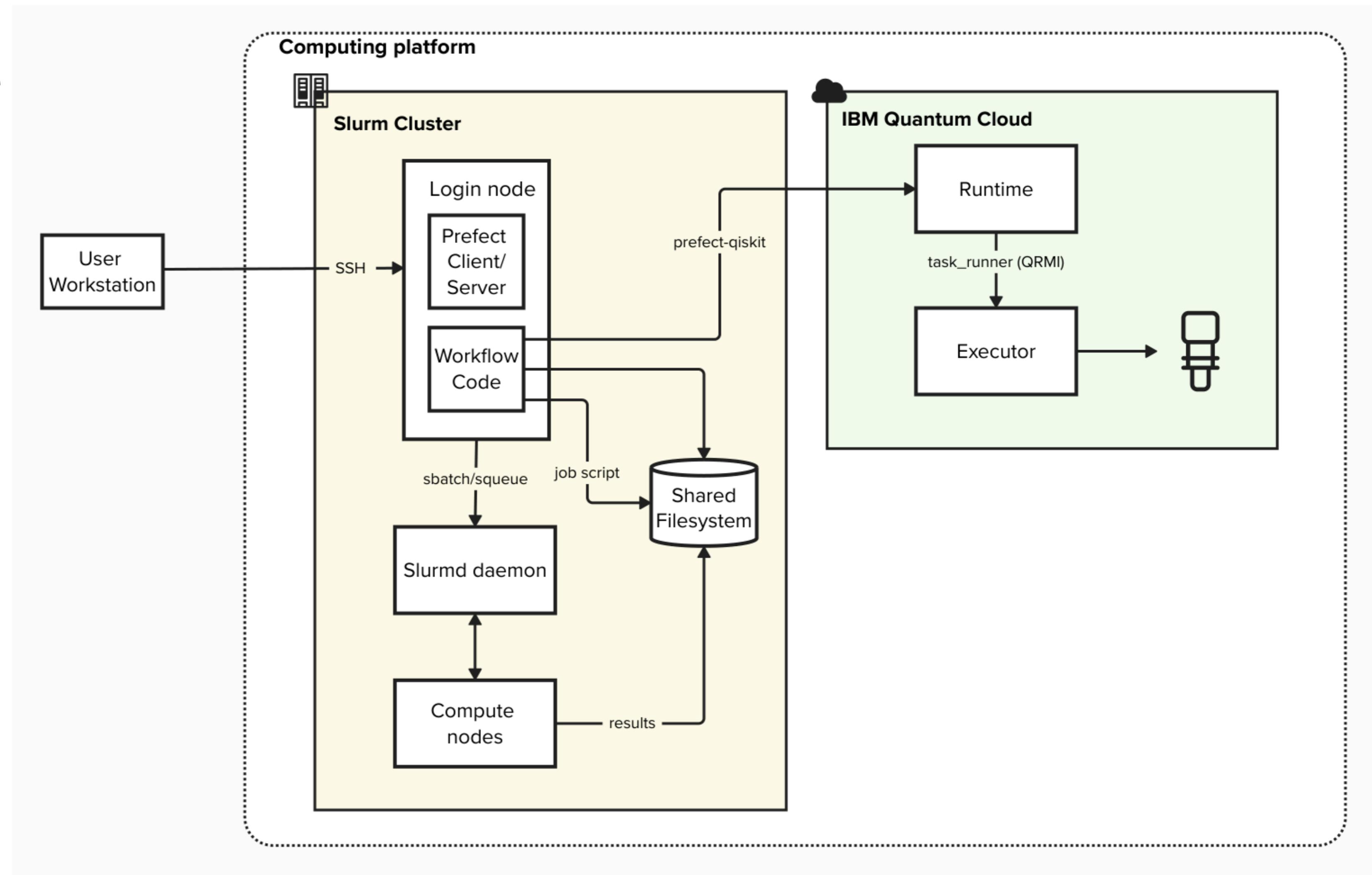
```
1 import asyncio
2 import json
3 from prefect import flow
4 from prefect.artifacts import create_table_artifact
5 from prefect.variables import Variable
6 from prefect_qiskit import QuantumRuntime
7 from qiskit import QuantumCircuit
8 from qiskit.transpiler import generate_preset_pass_manager
9 from get_counts_integration import BitCounter
10 from qiskit.primitives.containers.sampler_pub import SamplerPub
11 from qiskit import qasm3
12 from get_task_runner import TaskRunner
13 from qiskit_ibm_runtime.utils import RuntimeEncoder
14 from qiskit_ibm_runtime.utils.result_decoder import ResultDecoder
15
16 BITLEN = 10
17
18 @flow(name="slurm_tutorial")
19 async def main():
20     # Load configurations
21     runtime = await QuantumRuntime.load("ibm-runner")
22     counter = await BitCounter.load("slurm-tutorial")
23     options = await Variable.get("slurm-tutorial")
24     taskrunner = await TaskRunner.load("slurm-tutorial")
25
26     # Create a PUB payload
27     target = await runtime.get_target()
28     qc_ghz = QuantumCircuit(BITLEN)
29     qc_ghz.h(0)
30     qc_ghz.cx(0, range(1, BITLEN))
31     qc_ghz.measure_active()
32
33     pm = generate_preset_pass_manager(
34         optimization_level=3,
35         target=target,
36         seed_transpiler=123,
37     )
38     isa = pm.run(qc_ghz)
39     pub_like = (isa,) # Create a Primitive Unified Bloc
40
41     # Extract shots
42     shots = options.get("shots", 100000) # default to 100000 if not set
43
44     dict_pubs = []
45
46     # Create input.json for task_runner
47     coerced_pub = SamplerPub.coerce(pub_like, shots=shots)
48
49     # Generate OpenQASM3 string which can be consumed by IBM Quantum APIs
50     qasm3_str = qasm3.dumps(
51         coerced_pub.circuit,
52         disable_constants=True,
53         allow_aliasing=True,
54         experimental=qasm3.ExperimentalFeatures.SWITCH_CASE_V1,
55     )
56
57     if len(coerced_pub.circuit.parameters) == 0:
58         if coerced_pub.shots:
59             dict_pubs.append((qasm3_str, None, coerced_pub.shots))
60         else:
61             dict_pubs.append((qasm3_str))
62     else:
63         param_array = coerced_pub.parameter_values.as_array()
64         coerced_pub.circuit.parameters
65             .tolist()
66
67         if coerced_pub.shots:
68             dict_pubs.append((qasm3_str, param_array, coerced_pub.shots))
69         else:
70             dict_pubs.append((qasm3_str, param_array))
71
72     # Create SamplerV2 input
73     input_json = {
74         "pubs": dict_pubs,
75         "shots": shots,
76         "options": options,
77         "version": 2,
78         "support_qiskit": True,
79     }
80     print("Here is the input json:", input_json)
81
82     taskrunner_json = {"parameters": input_json, "program_id": "sampler"}
83     print("Here is the taskrunner json:", taskrunner_json)
84
85     filename = "/mnt/data/salaria/slurm_tutorial/input.json"
86     with open(filename, "w", encoding="utf-8") as primitive_input_file:
87         json.dump(taskrunner_json, primitive_input_file, cls=RuntimeEncoder, indent=2)
88
89     # Quantum execution
90     result = await taskrunner.run()
91
92     # Read output
93     with open('/mnt/data/salaria/slurm_tutorial/output.json', 'r') as f:
94         results = ResultDecoder.decode(f.read())
95
96     # MPI execution
97     bitstrings = results[0].data.meas.get_bitstrings()
98     counts = await counter.get(bitstrings)
99
100
101    # Save in Prefect artifacts
102    await create_table_artifact(
103        table=[list(counts.keys()), list(counts.values())],
104        key="sampler-count-dict",
105    )
106
107 if __name__ == "__main__":
108     asyncio.run(main())
109
```

System Architecture



Hybrid Application Development with Prefect Qiskit

- Run a workflow server in login node
 - Submit Quantum jobs
 - Submit HPC jobs
 - Wait for results of jobs independently
- Use Python to write workflow
 - Prefect
 - Prefect Qiskit block to submit quantum jobs
 - Prefect MPI block to submit MPI jobs
 - Predefined jobs: BitCount



Prefect Core Concepts

Flow (end-to-end workflow)

- The Flow represents the full QCSC iteration

Tasks (individual execution steps)

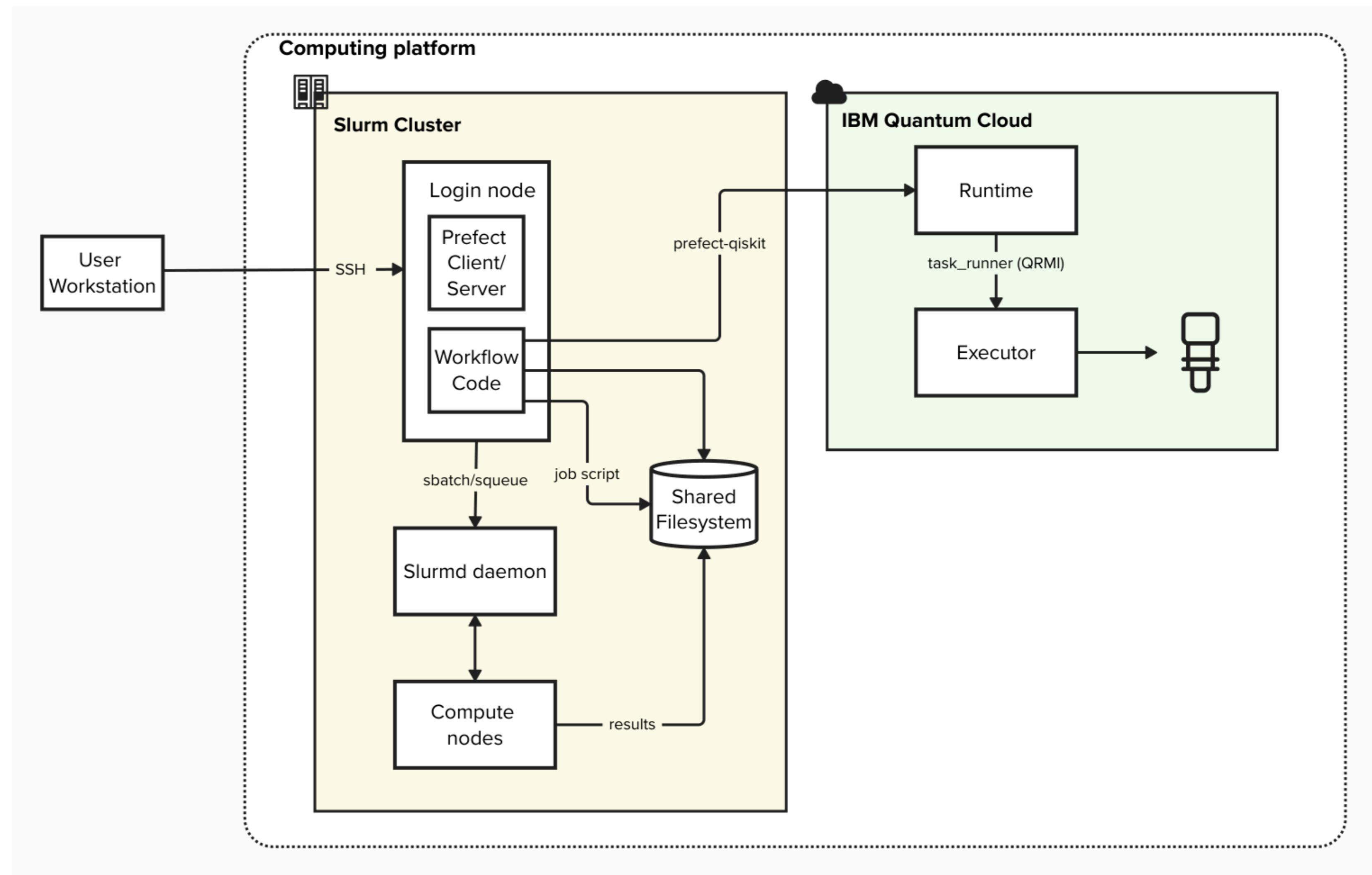
- Sampling Task: submit a slurm job to run Quantum sampling job.
- HPC Task: submit a slurm job to run MPI programs.

Blocks (reusable configuration + credentials)

- Quantum Blocks: IBM Quantum credentials (encrypted), runtime configuration, Slurm job configuration.
- HPC Blocks: Slurm job configuration.

Variables (run-time parameters)

- Quantum parameters: shots, circuit or sampler options.
- Algorithm parameters: iteration used by the workflow logic.



Prefect Core Concepts: Flow

Flow (end-to-end workflow)

- The Flow represents the full QCSC iteration

Tasks (individual execution steps)

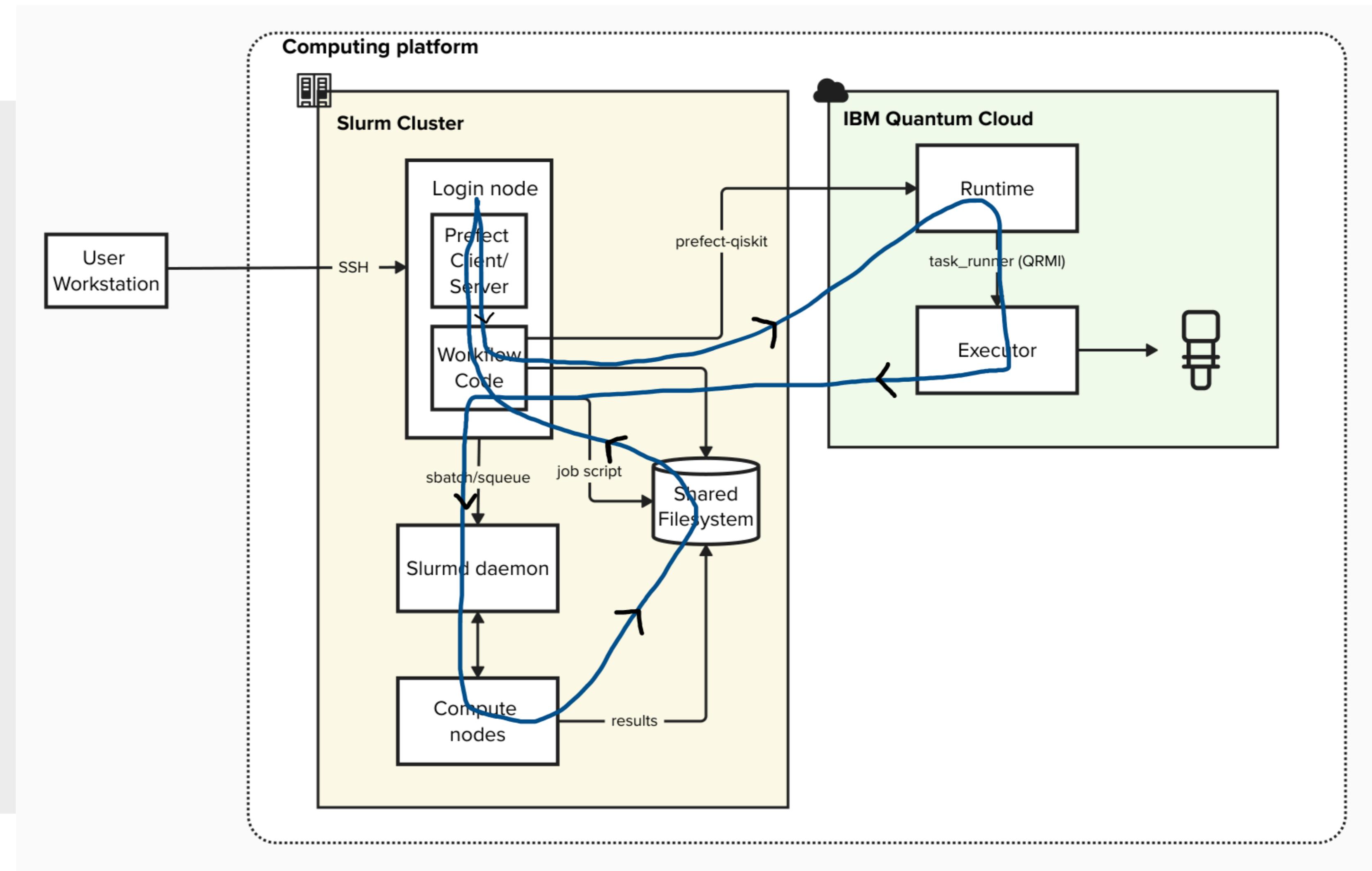
- Sampling Task: submit a slurm job to run Quantum sampling job.
- HPC Task: submit a slurm job to run MPI programs.

Blocks (reusable configuration + credentials)

- Quantum Blocks: IBM Quantum credentials, runtime configuration, Slurm job configuration.
- HPC Blocks: Slurm job configuration.

Variables (run-time parameters)

- Quantum parameters: shots, circuit or sampler options.
- Algorithm parameters: iteration used by the workflow logic.



Prefect Core Concepts: Tasks

Flow (end-to-end workflow)

- The Flow represents the full QCSC iteration

Tasks (individual execution steps)

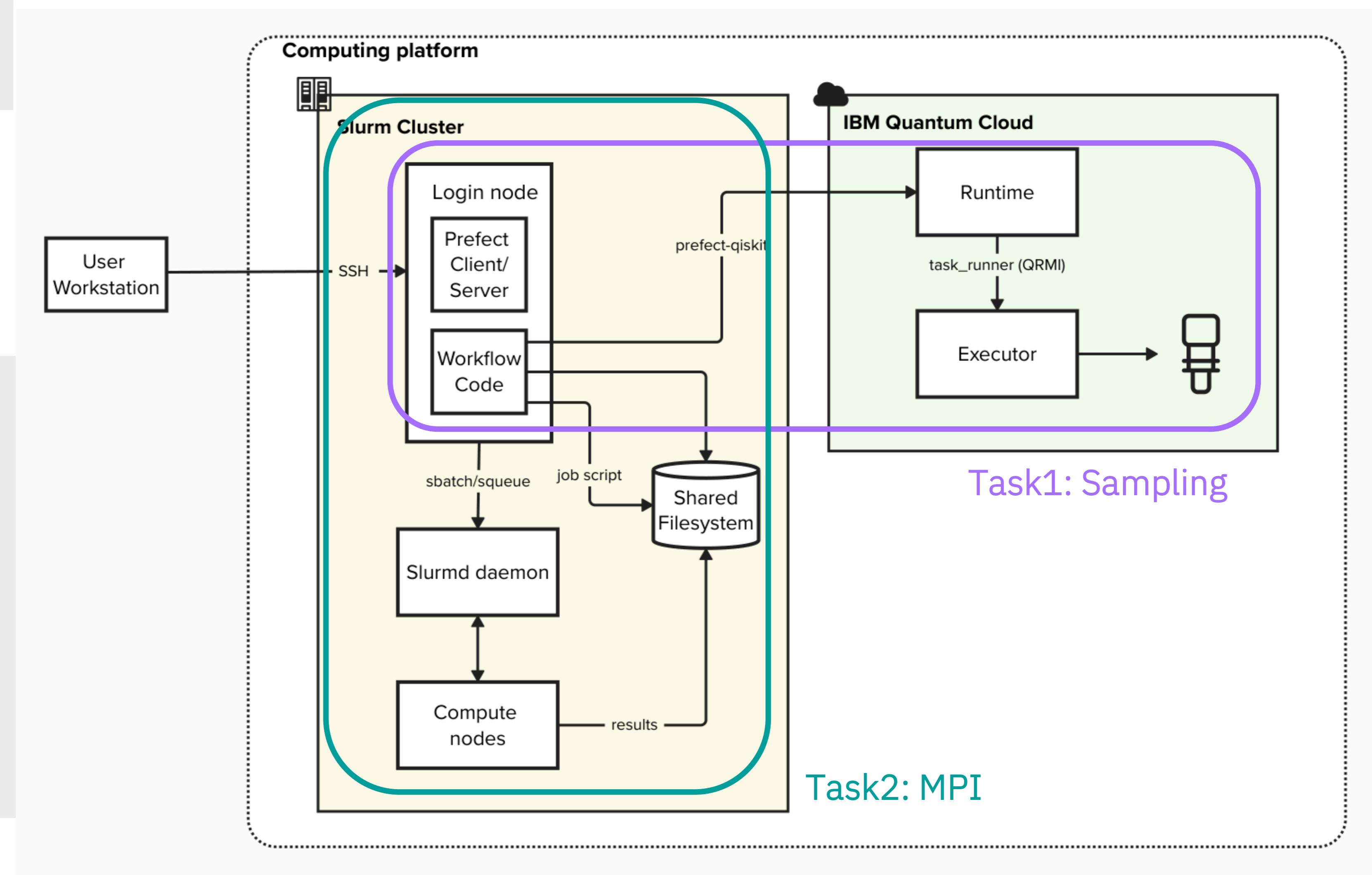
- Sampling Task: submit a slurm job to run Quantum sampling job.
- HPC Task: submit a slurm job to run MPI programs.

Blocks (reusable configuration + credentials)

- Quantum Blocks: IBM Quantum credentials, runtime configuration, Slurm job configuration.
- HPC Blocks: Slurm job configuration.

Variables (run-time parameters)

- Quantum parameters: shots, circuit or sampler options.
- Algorithm parameters: iteration used by the workflow logic.



Prefect Core Concepts: Blocks

Blocks

- Quantum Block (credentials, resource)
- HPC Block (queue, nodes, launcher)

Flow (end-to-end workflow)

- The Flow represents the full QCSC iteration

Tasks (individual execution steps)

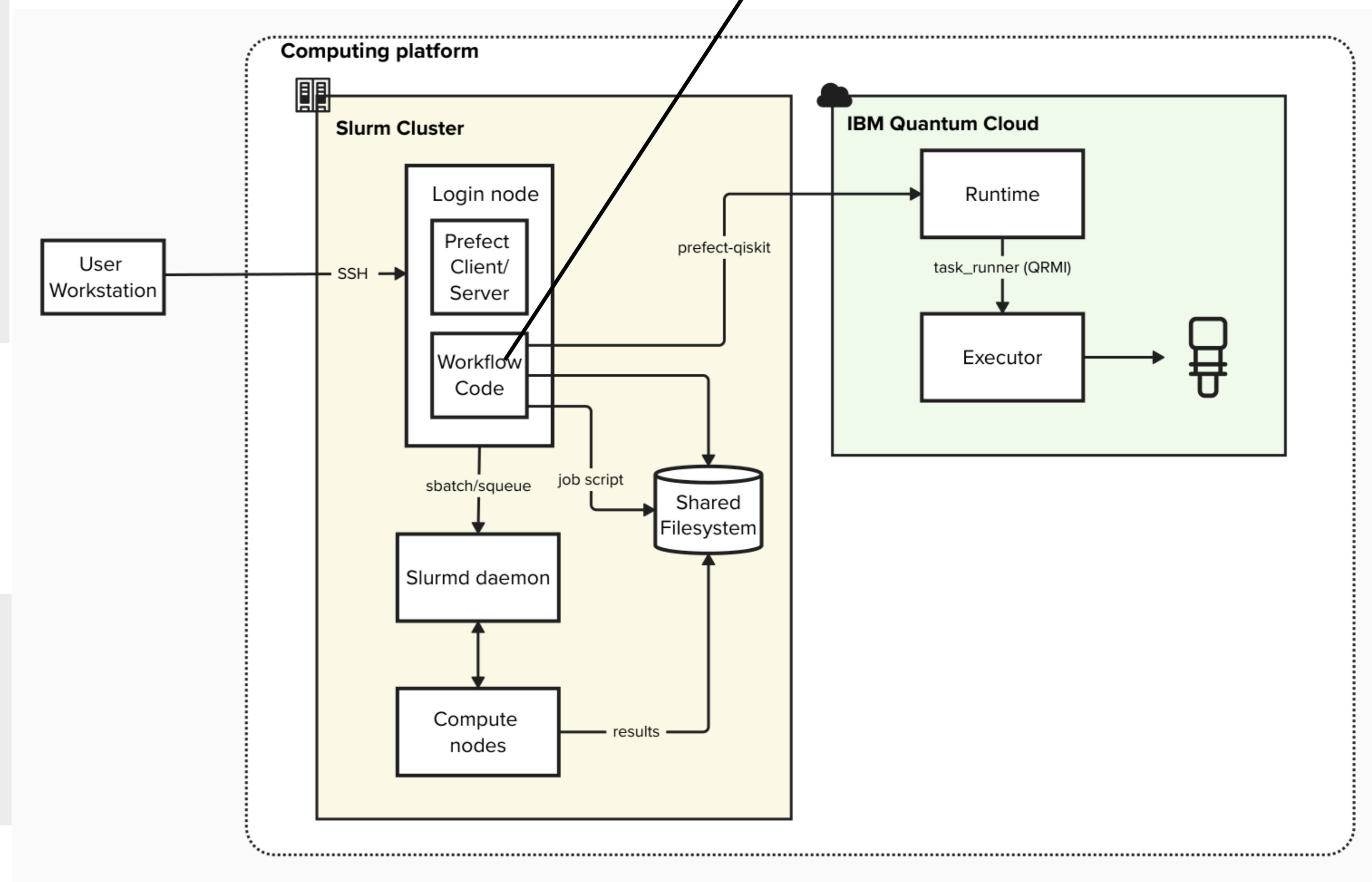
- Sampling Task: submit a slurm job to run Quantum sampling job.
- HPC Task: submit a slurm job to run MPI programs.

Blocks (reusable configuration + credentials)

- Quantum Blocks: IBM Quantum credentials, runtime configuration, Slurm job configuration.
- HPC Blocks: Slurm job configuration.

Variables (run-time parameters)

- Quantum parameters: shots, circuit or sampler options.
- Algorithm parameters: iteration used by the workflow logic.



Prefect Core Concepts: Variables

Flow (end-to-end workflow)

- The Flow represents the full QCSC iteration

Tasks (individual execution steps)

- Sampling Task: submit a slurm job to run Quantum sampling job.
- HPC Task: submit a slurm job to run MPI programs.

Blocks (reusable configuration + credentials)

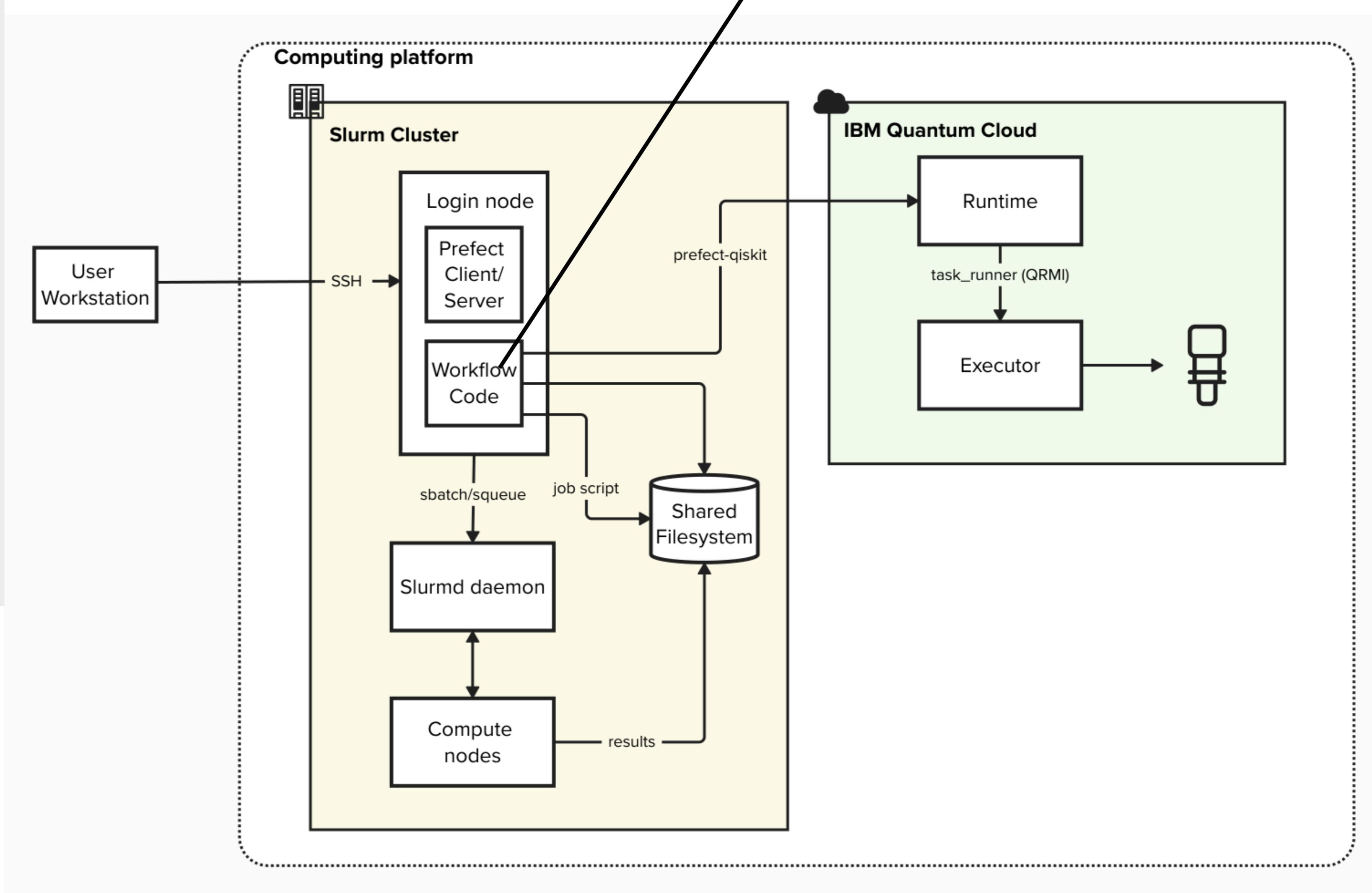
- Quantum Blocks: IBM Quantum credentials, runtime configuration, Slurm job configuration.
- HPC Blocks: Slurm job configuration.

Variables (run-time parameters)

- Quantum parameters: shots, circuit or sampler options.
- Algorithm parameters: iteration used by the workflow logic.

Variables

- Quantum parameters (shots, sampler options)
- Algorithm parameters



Prefect: All Together

Blocks

- Quantum Block (credentials, resource)
- HPC Block (queue, nodes, launcher)

Variables

- Quantum parameters (shots, sampler options)
- Algorithm parameters

Flow (end-to-end workflow)

- The Flow represents the full QCSC iteration

Tasks (individual execution steps)

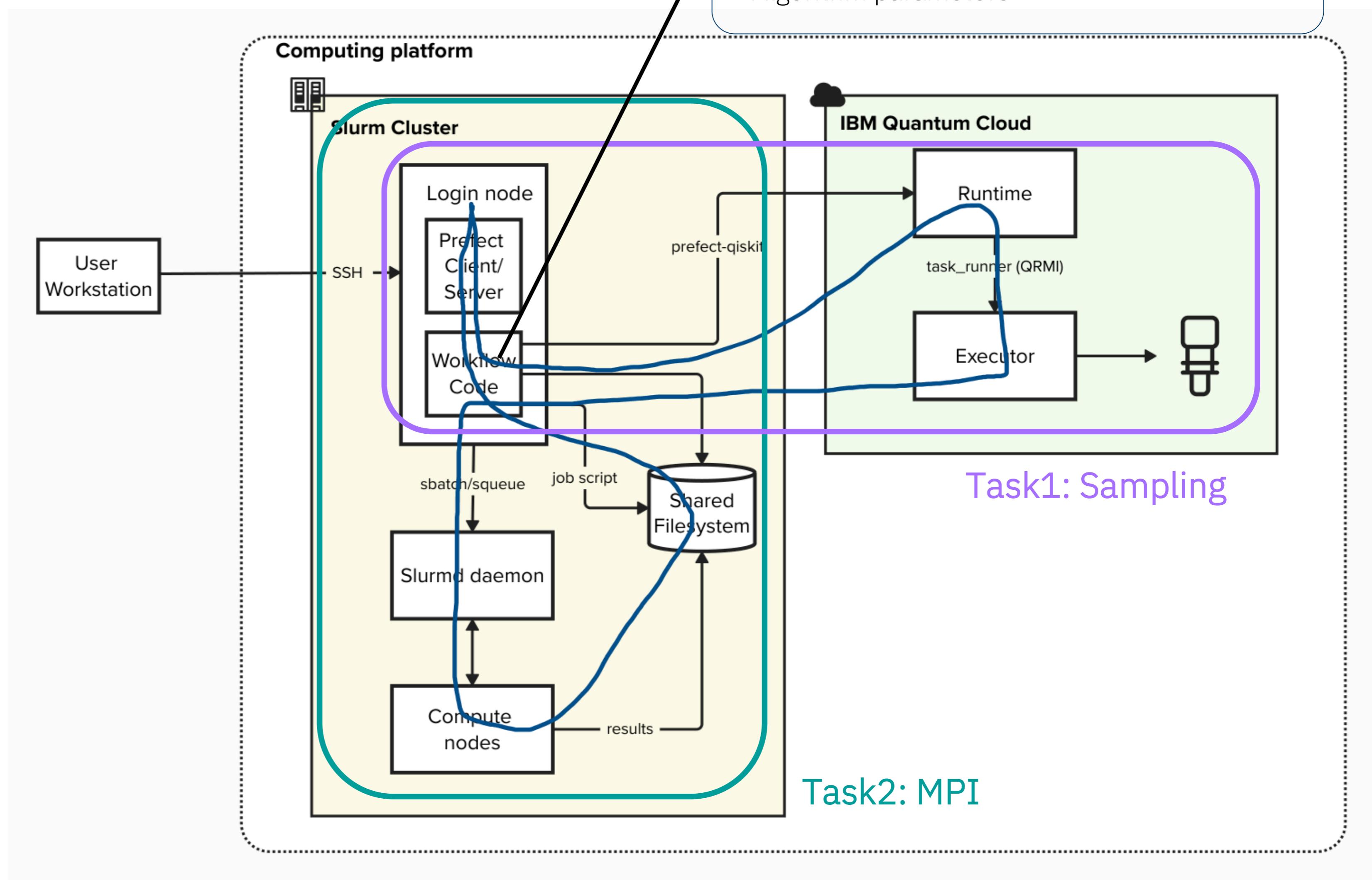
- Sampling Task: submit a slurm job to run Quantum sampling job.
- HPC Task: submit a slurm job to run MPI programs.

Blocks (reusable configuration + credentials)

- Quantum Blocks: IBM Quantum credentials, runtime configuration, Slurm job configuration.
- HPC Blocks: Slurm job configuration.

Variables (run-time parameters)

- Quantum parameters: shots, circuit or sampler options.
- Algorithm parameters: iteration used by the workflow logic.



Using Prefect Blocks

The screenshot shows the Prefect Catalog interface on a dark-themed browser window. The left sidebar contains navigation links: Dashboard, Runs, Flows, Deployments, Work Pools, **Blocks**, Variables, Automations, Event Feed, and Concurrency. A message at the top says, "Can't find a block for your service? Check out the [docs](#) for a full list of integrations in the SDK." Below this, it displays "62 Blocks". A search bar on the right says "Search blocks". The main area is a grid of cards, each representing a different block:

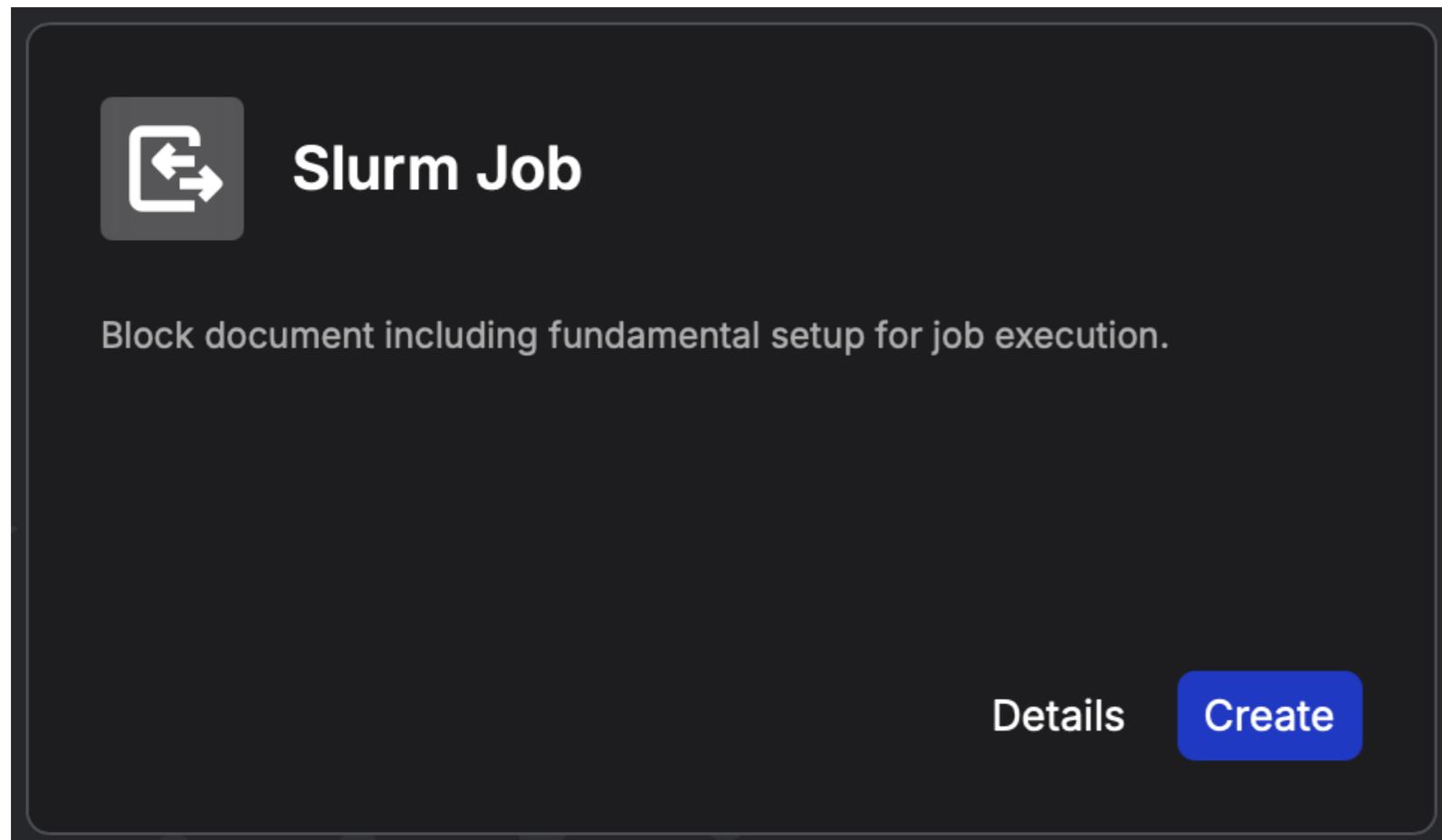
- AWS Credentials**: Block used to manage authentication with AWS. AWS authentication is handled via the `boto3` module. Refer to the [boto3 docs](#) for more info about the possible credential configurations. This block is part of the `prefect-aws` collection. Install `prefect-aws` with `pip install prefect-aws` to use this block.
- AWS Secret**: Manages a secret in AWS's Secrets Manager. This block is part of the `prefect-aws` collection. Install `prefect-aws` with `pip install prefect-aws` to use this block.
- Azure Blob Storage Container**: Represents a container in Azure Blob Storage. This class provides methods for downloading and uploading files and folders to and from the Azure Blob Storage container. This block is part of the `prefect-azure` collection. Install `prefect-azure` with `pip install prefect-azure` to use this block.
- Azure Blob Storage Credentials**: Stores credentials for authenticating with Azure Blob Storage. This block is part of the `prefect-azure` collection. Install `prefect-azure` with `pip install prefect-azure` to use this block.
- Azure Container Instance Credentials**: Block used to manage Azure Container Instances authentication. Stores Azure Service Principal authentication data. This block is part of the `prefect-azure` collection. Install `prefect-azure` with `pip install prefect-azure` to use this block.
- Azure Cosmos DB Credentials**: Block used to manage Cosmos DB authentication with Azure. Azure authentication is handled via the `azure` module through a connection string. This block is part of the `prefect-azure` collection. Install `prefect-azure` with `pip install prefect-azure` to use this block.
- AzureML Credentials**: Block used to manage authentication with AzureML. Azure authentication is handled via the `azure` module. This block is part of the `prefect-azure` collection. Install `prefect-azure` with `pip install prefect-azure` to use this block.
- BigQuery Warehouse**: A block for querying a database with BigQuery. Upon instantiating, a connection to BigQuery is established and maintained for the life of the object until the `close` method is called.
- Bit Counter**: A block for tracking the number of bits processed.

At the bottom left, there are buttons for "Ready to scale?", "Upgrade", "Join the Community", and "Settings".

Prefect provides some pre-configured configurations

Creating custom Prefect block

- `class SlurmJobBlock:`
encapsulates slurm job configuration and execution logic
- Provides reusable interface to submit jobs to the slurm cluster



```
1  """Base block document for HPC job configuration."""
2
3  from pathlib import Path
4  from typing import Literal
5
6  from prefect.blocks.core import Block
7  from pydantic import Field
8
9  from .executor import BatchExecutor, JobExecutorBase, LocalExecutor
10
11
12  class SlurmJobBlock(Block):
13      """Block document including fundamental setup for job execution."""
14
15      _block_type_name = "Slurm Job"
16      _block_type_slug = "slurm_job"
17
18      work_root: str = Field(
19          description=(
20              "Root directory to store temporary files for program execution. Usually a sub-directory is created per job."
21          ),
22          title="Root Directory",
23      )
24
25      executable: str = Field(
26          description="Absolute path of the executable to run in the job. Arguments must be separately specified.",
27          title="Executable",
28      )
29
30      executor: Literal[
31          "sbatch",
32          "local",
33      ] = Field(
34          default="local",
35          description="A type of job scheduler to run the executable.",
36          title="Executor",
37      )
38
39      launcher: Literal[
40          "single",
41          "srun",
42          "mpirun",
43      ] = Field(
44          default="single",
45          description=(
46              "A command to control program execution environment such as MPI. "
47              "When 'single' is selected, the executable is directly executed in the job."
48          ),
49          title="Launcher",
50      )
```

Custom Prefect block: Slurm Job

The screenshot shows the Prefect UI for creating a new block named "Slurm Job". The configuration fields are as follows:

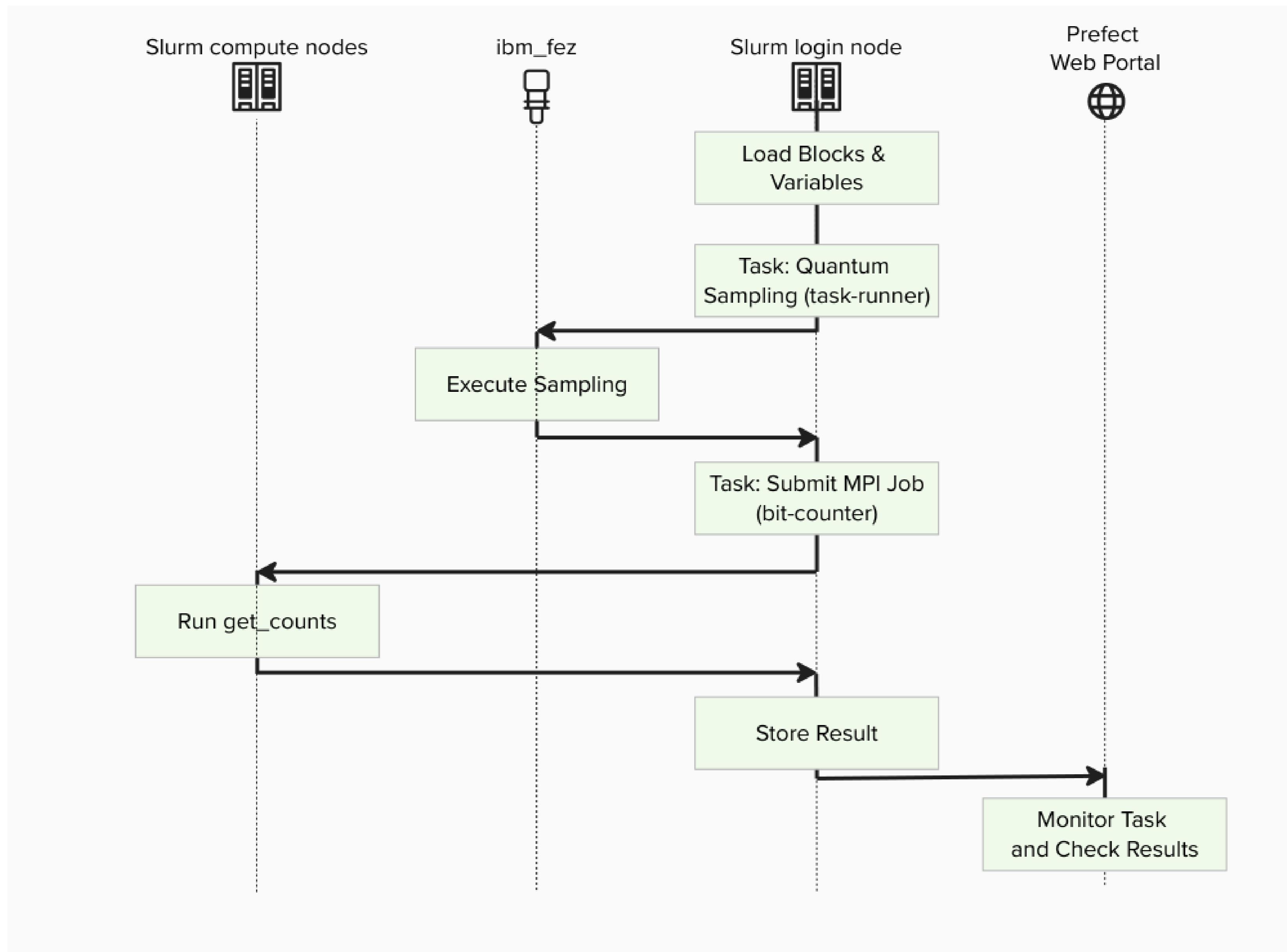
- Block Name:** Slurm Job
- Root Directory:** (Input field)
- Executable:** (Input field)
- Executor (Optional):** local
- Launcher (Optional):** single
- Partition:** compute
- QPU:** (Input field)

```
1  """Base block document for HPC job configuration."""
2
3  from pathlib import Path
4  from typing import Literal
5
6  from prefect.blocks.core import Block
7  from pydantic import Field
8
9  from .executor import BatchExecutor, JobExecutorBase, LocalExecutor
10
11
12  class SlurmJobBlock(Block):
13      """Block document including fundamental setup for job execution."""
14
15      _block_type_name = "Slurm Job"
16      _block_type_slug = "slurm_job"
17
18      work_root: str = Field(
19          description=(
20              "Root directory to store temporary files for program execution. Usually a sub-directory is created per job."
21          ),
22          title="Root Directory",
23      )
24
25      executable: str = Field(
26          description="Absolute path of the executable to run in the job. Arguments must be separately specified.",
27          title="Executable",
28      )
29
30      executor: Literal[
31          "sbatch",
32          "local",
33      ] = Field(
34          default="local",
35          description="A type of job scheduler to run the executable.",
36          title="Executor",
37      )
38
39      launcher: Literal[
40          "single",
41          "srun",
42          "mpirun",
43      ] = Field(
44          default="single",
45          description=(
46              "A command to control program execution environment such as MPI. "
47              "When 'single' is selected, the executable is directly executed in the job."
48          ),
49          title="Launcher",
50      )
```

QCSC Workflow: BitCount

```
1 import asyncio
2 import json
3 from prefect import flow
4 from prefect.artifacts import create_table_artifact
5 from prefect.variables import Variable
6 from prefect_qiskit import QuantumRuntime
7 from qiskit import QuantumCircuit
8 from qiskit.transpiler import generate_preset_pass_manager
9 from get_counts_integration import BitCounter
10 from qiskit.primitives.containers.sampler_pub import SamplerPub
11 from qiskit import qasm3
12 from get_task_runner import TaskRunner
13 from qiskit_ibm_runtime.utils import RuntimeEncoder
14 from qiskit_ibm_runtime.utils.result_decoder import ResultDecoder
15
16 BITLEN = 10
17
18 @flow(name="slurm_tutorial")
19 async def main():
20     # Load configurations
21     runtime = await QuantumRuntime.load("ibm-runner")
22     counter = await BitCounter.load("slurm-tutorial")
23     options = await Variable.get("slurm-tutorial")
24     taskrunner = await TaskRunner.load("slurm-tutorial")
25
26     # Create a PUB payload
27     target = await runtime.get_target()
28     qc_ghz = QuantumCircuit(BITLEN)
29     qc_ghz.h(0)
30     qc_ghz.cx(0, range(1, BITLEN))
31     qc_ghz.measure_active()
32
33     pm = generate_preset_pass_manager(
34         optimization_level=3,
35         target=target,
36         seed_transpiler=123,
37     )
38     isa = pm.run(qc_ghz)
39     pub_like = (isa,) # Create a Primitive Unified Bloc
40
41     # Extract shots
42     shots = options.get("shots", 100000) # default to 100000 if not set
43
44     dict_pubs = []
45
46     # Create input.json for task_runner
47     coerced_pub = SamplerPub.coerce(pub_like, shots=shots)
48
49     # Generate OpenQASM3 string which can be consumed by IBM Quantum APIs
50     qasm3_str = qasm3.dumps(
51         coerced_pub.circuit,
52         disable_constants=True,
53         allow_aliasing=True,
54         experimental=qasm3.ExperimentalFeatures.SWITCH_CASE_V1,
55     )
56
57     if len(coerced_pub.circuit.parameters) == 0:
58         if coerced_pub.shots:
59             dict_pubs.append((qasm3_str, None, coerced_pub.shots))
60         else:
61             dict_pubs.append((qasm3_str))
62     else:
63         param_array = coerced_pub.parameter_values.as_array()
64         coerced_pub.circuit.parameters
65             .tolist()
66
67         if coerced_pub.shots:
68             dict_pubs.append((qasm3_str, param_array, coerced_pub.shots))
69         else:
70             dict_pubs.append((qasm3_str, param_array))
71
72     # Create SamplerV2 input
73     input_json = {
74         "pubs": dict_pubs,
75         "shots": shots,
76         "options": options,
77         "version": 2,
78         "support_qiskit": True,
79     }
80     print("Here is the input json:", input_json)
81
82     taskrunner_json = {"parameters": input_json, "program_id": "sampler"}
83     print("Here is the taskrunner json:", taskrunner_json)
84
85     filename = "/mnt/data/salaria/slurm_tutorial/input.json"
86     with open(filename, "w", encoding="utf-8") as primitive_input_file:
87         json.dump(taskrunner_json, primitive_input_file, cls=RuntimeEncoder, indent=2)
88
89     # Quantum execution
90     result = await taskrunner.run()
91
92     # Read output
93     with open('/mnt/data/salaria/slurm_tutorial/output.json', 'r') as f:
94         results = ResultDecoder.decode(f.read())
95
96     # MPI execution
97     bitstrings = results[0].data.meas.get_bitstrings()
98     counts = await counter.get(bitstrings)
99
100
101    # Save in Prefect artifacts
102    await create_table_artifact(
103        table=[list(counts.keys()), list(counts.values())],
104        key="sampler-count-dict",
105    )
106
107 if __name__ == "__main__":
108     asyncio.run(main())
109
```

Prefect Workflow: BitCount



BitCount – Load Configurations

- Line 21: Quantum runtime settings referencing credentials
- Line 22: MPI block
- Line 23: Variables
- Line 24: Quantum block

```
1 import asyncio
2 import json
3 from prefect import flow
4 from prefect.artifacts import create_table_artifact
5 from prefect.variables import Variable
6 from prefect_qiskit import QuantumRuntime
7 from qiskit import QuantumCircuit
8 from qiskit.transpiler import generate_preset_pass_manager
9 from get_counts_integration import BitCounter
10 from qiskit.primitives.containers.sampler_pub import SamplerPub
11 from qiskit import qasm3
12 from get_task_runner import TaskRunner
13 from qiskit_ibm_runtime.utils import RuntimeEncoder
14 from qiskit_ibm_runtime.utils.result_decoder import ResultDecoder
15
16 BITLEN = 10
17
18 @flow(name="slurm_tutorial")
19 async def main():
20     # Load configurations
21     runtime = await QuantumRuntime.load("ibm-runner")
22     counter = await BitCounter.load("slurm-tutorial")
23     options = await Variable.get("slurm-tutorial")
24     taskrunner = await TaskRunner.load("slurm-tutorial")
25
26     # Create a PUB payload
27     target = await runtime.get_target()
28     qc_ghz = QuantumCircuit(BITLEN)
29     qc_ghz.h(0)
30     qc_ghz.cx(0, range(1, BITLEN))
31     qc_ghz.measure_active()
```

BitCount – Prepare Quantum Circuit

- Line 26-39: Define quantum circuit and transpile

```
88
89     # Quantum execution
90     result = await taskrunner.run()
91
92     # Read output
93     with open('/mnt/data/salaria/slurm_tutorial/output.json', 'r') as f:
94         results = ResultDecoder.decode(f.read())
95
96     # MPI execution
97     bitstrings = results[0].data.meas.get_bitstrings()
98     counts = await counter.get(bitstrings)
99
100    # Save in Prefect artifacts
101    await create_table_artifact(
102        table=[list(counts.keys()), list(counts.values())],
103        key="sampler-count-dict",
104    )
105
106
107 if __name__ == "__main__":
108     asyncio.run(main())
109
```

BitCount – Prepare Quantum Environment

- Line 46-87: Create input file for task_runner (QRMI)

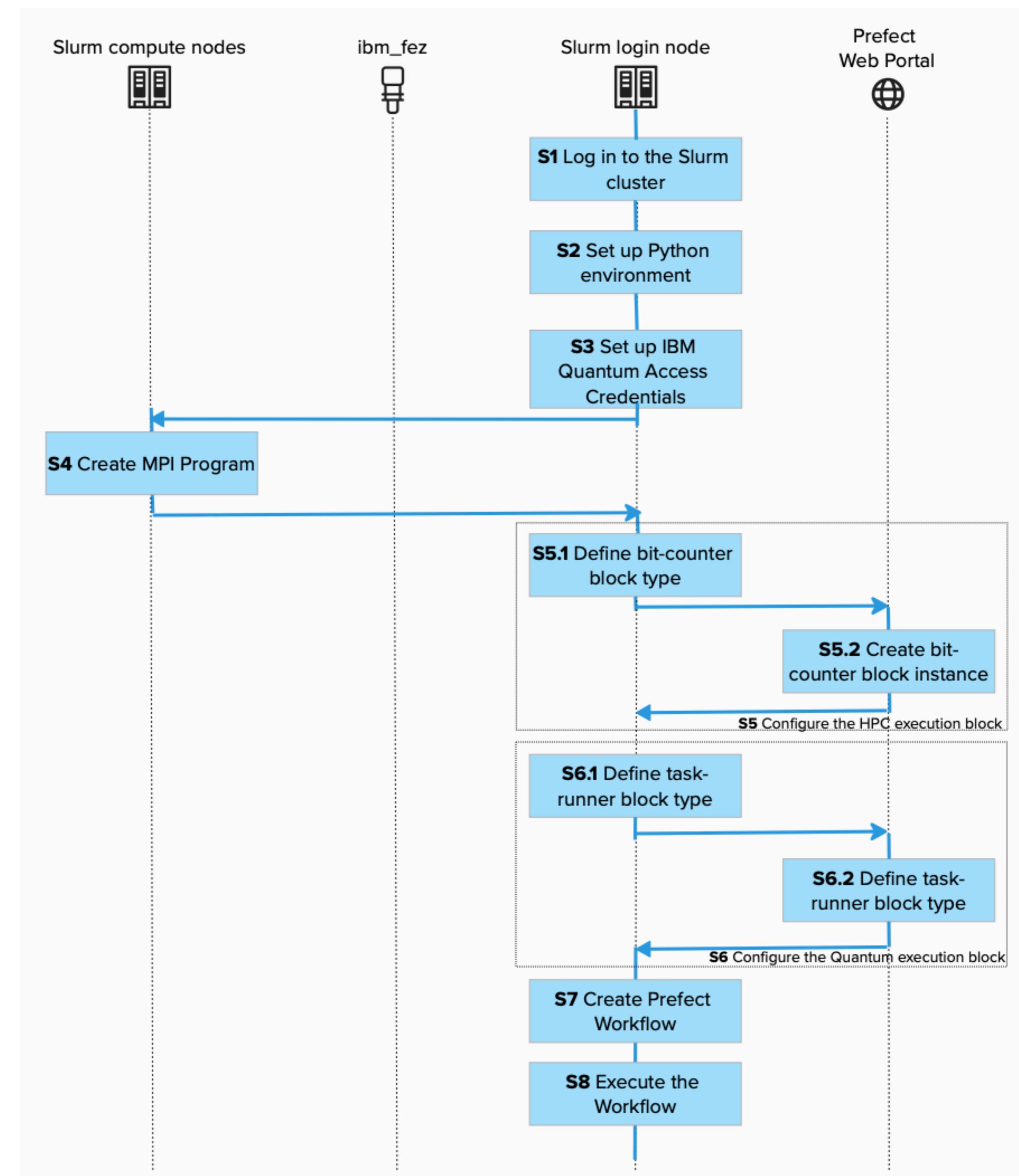
```
46     # Create input.json for task_runner
47     coerced_pub = SamplerPub.coerce(pub_like, shots=shots)
48
49     # Generate OpenQASM3 string which can be consumed by IBM Quantum APIs
50     qasm3_str = qasm3.dumps(
51         coerced_pub.circuit,
52         disable_constants=True,
53         allow_aliasing=True,
54         experimental=qasm3.ExperimentalFeatures.SWITCH_CASE_V1,
55     )
56
57     if len(coerced_pub.circuit.parameters) == 0:
58         if coerced_pub.shots:
59             dict_pubs.append((qasm3_str, None, coerced_pub.shots))
60         else:
61             dict_pubs.append((qasm3_str))
62     else:
63         param_array = coerced_pub.parameter_values.as_array(
64             coerced_pub.circuit.parameters
65             ).tolist()
66
67         if coerced_pub.shots:
68             dict_pubs.append((qasm3_str, param_array, coerced_pub.shots))
69         else:
70             dict_pubs.append((qasm3_str, param_array))
71
72     # Create SamplerV2 input
73     input_json = {
74         "pubs": dict_pubs,
75         "shots": shots,
76         "options": options,
77         "version": 2,
78         "support_qiskit": True,
79     }
80     print("Here is the input json:", input_json)
81
82     taskrunner_json = {"parameters": input_json, "program_id": "sampler"}
83     print("Here is the taskrunner json:", taskrunner_json)
84
85     filename = "/mnt/data/salaria/slurm_tutorial/input.json"
86     with open(filename, "w", encoding="utf-8") as primitive_input_file:
87         json.dump(taskrunner_json, primitive_input_file, cls=RuntimeEncoder, indent=2)
```

BitCount – Execute blocks and save results

- Line 90: Quantum job execution
- Line 93-94: Get quantum result and decode
- Line 97-98: MPI job execution
- Line 101-104: save result as sampler-count-dict

```
88
89     # Quantum execution
90     result = await taskrunner.run()
91
92     # Read output
93     with open('/mnt/data/salaria/slurm_tutorial/output.json', 'r') as f:
94         results = ResultDecoder.decode(f.read())
95
96     # MPI execution
97     bitstrings = results[0].data.meas.get_bitstrings()
98     counts = await counter.get(bitstrings)
99
100    # Save in Prefect artifacts
101    await create_table_artifact(
102        table=[list(counts.keys()), list(counts.values())],
103        key="sampler-count-dict",
104    )
105
106
107 if __name__ == "__main__":
108     asyncio.run(main())
109
```

BitCount Demo



BitCount Run

 Runs / fanatic-fossa

Completed | 2026/01/19 03:36:49 PM | 1m 39s | 2 Task runs

Flow  slurm_tutorial

Dashboard

Runs

Flows

Deployments

Work Pools

Blocks

Variables

Automations

Event Feed

Concurrency

36:30 PM 3:37:00 PM 3:37:30 PM 3:38:00 PM 3:38:30 PM 3:39:00 PM 3:39:30 PM 3:40:00 PM 3:40:30 PM

run_task_runner-dc5 (run_slurm-182)

slurm-job-metrics

get_counts_mpi-178 (run_slurm-74d)

slurm-job-metrics

sampler-count-dict

4 3

Logs Task Runs Subflow Runs Artifacts Details Parameters Job Variables

Level: all | Oldest to newest | 

Ready to scale? [Upgrade](#)

Join the Community

Settings

INFO Beginning flow run 'fanatic-fossa' for flow 'slurm_tutorial' 03:36:49 PM prefect.flow_runs

INFO Created SLURM job 61 03:36:54 PM run_slurm-182 prefect.task_runs

INFO Job 61 finished with state COMPLETED and exit code 0 03:38:14 PM run_slurm-182 prefect.task_runs

INFO 2026-01-19 06:36:57,121 INFO Task ID: d5mt221h2mqc739bacm0 03:38:14 PM run_slurm-182

Tutorial Files



<https://github.com/ohtanim/SCA-HPCAsia-2026>