iQuHACK 2026 IonQ Challenge Report

Team: theLion
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Result: 30/30 Nodes Captured (Complete Graph Dominance)

Executive Summary

Our strategy combined a robust **LOCC-compliant Entanglement Distillation protocol** with an **autonomous, budget-aware agent** to systematically capture the network. By prioritizing self-sustainability (nodes with bonus bell pairs) and using adaptive resource allocation, we maximized territory while maintaining a distinct advantage over competitors.

1. Entanglement Distillation Methodology

We implemented a variation of the **DEJMPS** protocol, adapted for the specific LOCC constraints of the challenge.

Circuit Design

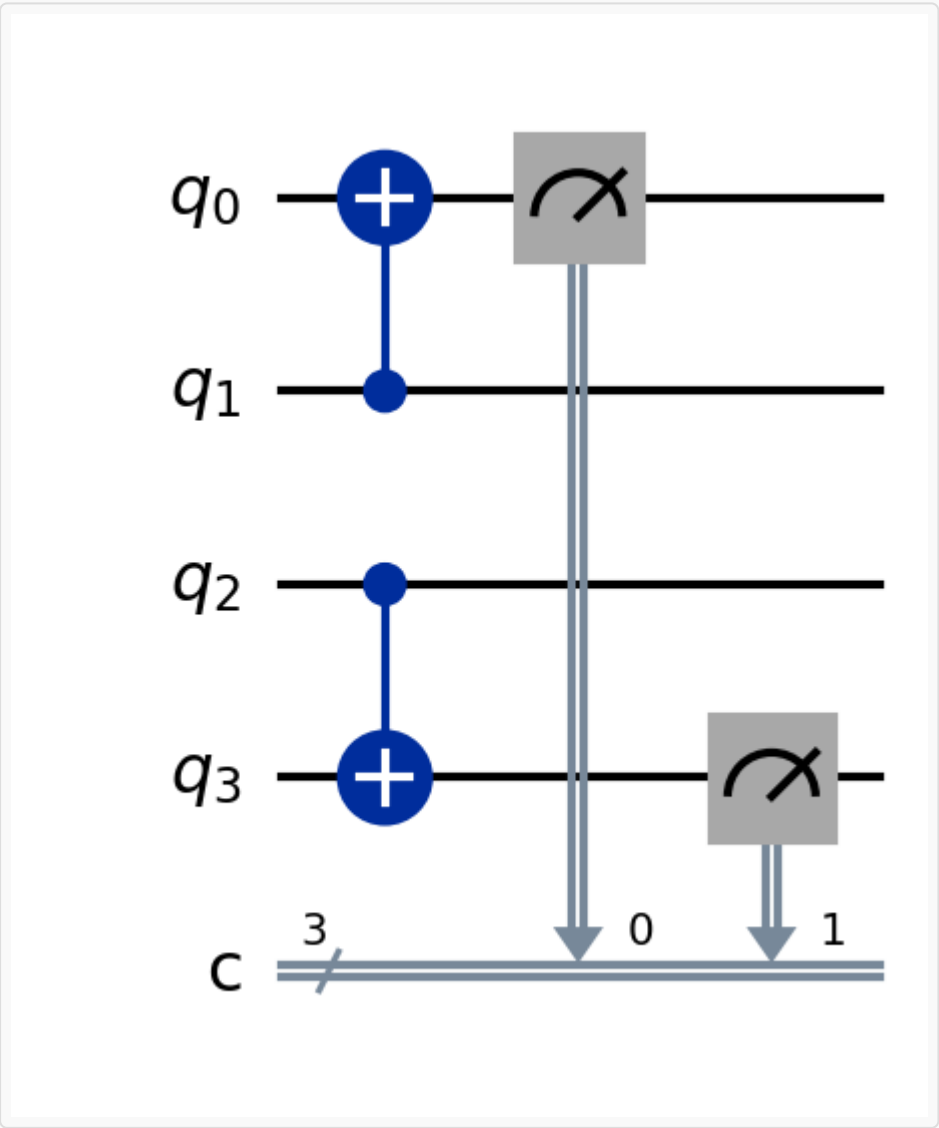
- **Alice's Qubits:** 0 to k-1
- **Bob's Qubits:** k to 2k-1
- **Target Pair:** Qubits (k-1) and k (The "innermost" pair)
- **Ancilla Pairs:** All other pairs

Algorithm Steps

1. **Bit-Flip Correction (CNOTs):** We apply local CNOT gates targeting the Ancilla pairs, controlled by the Target pair.
2. **Parity Measurement:** Both parties measure their Ancilla qubits.

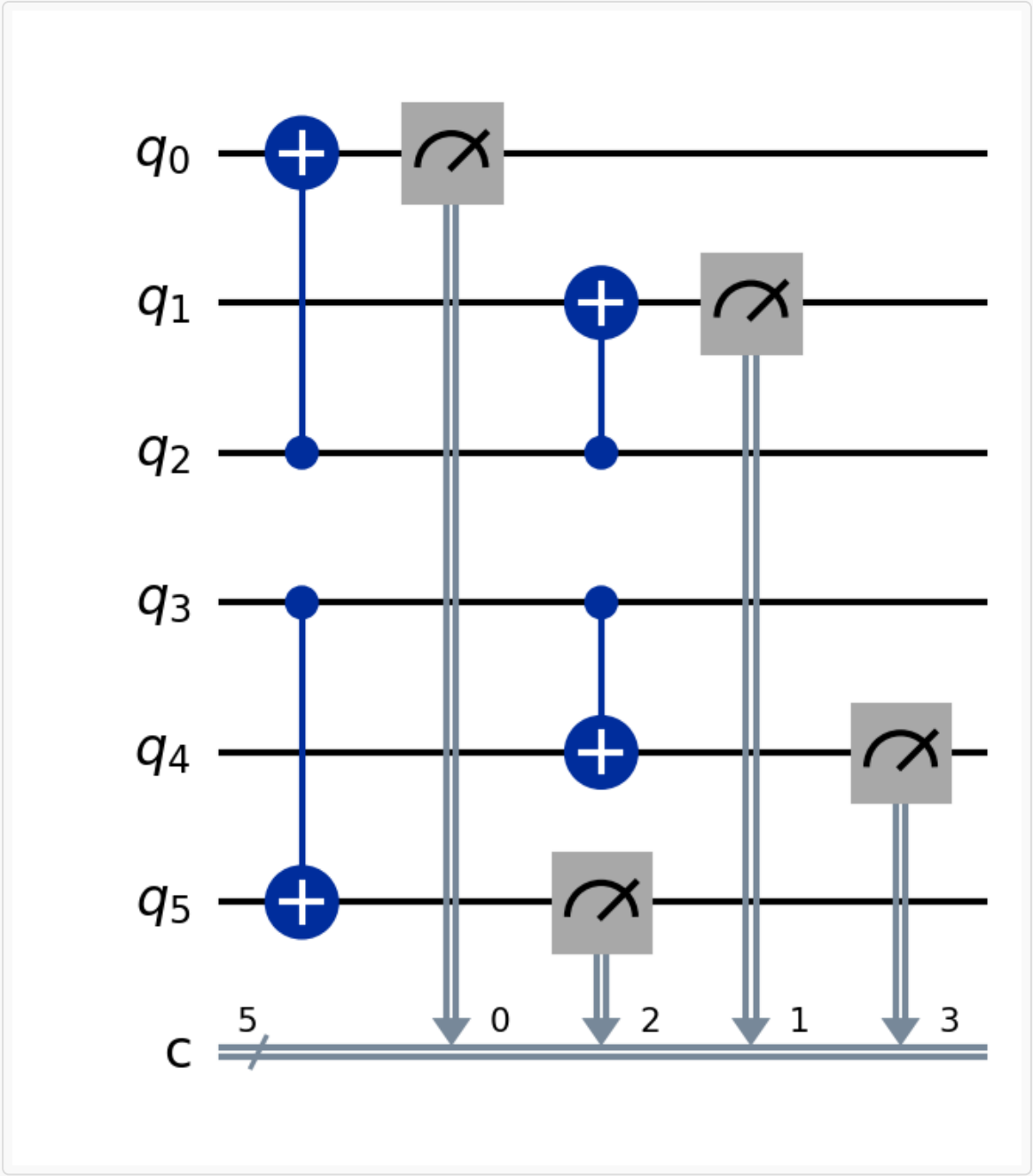
3. **Flag-based Post-Selection:** We compute the parity check `Check = m_A ^ m_B`. If any pair fails (XOR result is 1), the distillation is flagged as failed.

Figure 1: Distillation Circuit for k=2 (1 Ancilla Pair)



Alice (q0, q1) and Bob (q2, q3) use pair (0,3) to purify (1,2).

Figure 2: Distillation Circuit for k=3 (2 Ancilla Pairs)



Two ancilla pairs are used to purify the central pair.

2. Autonomous Network Strategy

To achieve 100% map coverage, we developed an `AutoPlayer` agent with the following heuristics:

Adaptive Resource Allocation ("Thrifty" Heuristic)

The agent dynamically selects the number of Bell pairs (k):

- First attempt: **k=2** (Cost: 2). High fidelity often allows this cheapest option.
- Fallback: Scale to **k=3** or **k=4** only if fidelity requirements are not met.

Priority Queueing

Edges were ranked by utility score:

```
Score = (100 * BonusPairs) + UtilityQubits - (0.1 * Difficulty)
```

- **Sustainability:** Bonus Bell Pair nodes were critical to maintain a positive budget.
- **Expansion:** The agent always targeted nodes not currently owned.