TCS Quantum Challenge: Idea Summary for Challenge 3 - Optimising Fleet Allocation

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I. Problem Statement

The aircraft fleeting and routing problem involves assigning minimum-cost routes to aircraft to cover scheduled flights, ensuring each flight is served by exactly one aircraft while meeting maintenance and activity constraints.

II. Solution Approach

In addressing this, a hybrid approach utilizing both classical and quantum methods have been adopted. Data preprocessing is conducted classically to prepare input for quantum method. Quantum Alternating Operator Ansatz (QAOA) is employed to obtain solutions, with classical data pre-processed for feasible allocation and optimized using QAOA with mixers. QAOA with mixers is employed to address constraints, with a Controlled Bit-flip mixer ensuring feasibility. Decision variables of the Binary Integer Programming (BIP) model are represented as qubits, with all feasible combinations also encoded as qubits. The objective function aims to minimize total operating costs while maximizing aircraft utilization, incorporating aircraft cost and differences in forecasted seats and capacity with weightage. The objective function is defined as summation of aircraft cost, deficit in seats and flight counts with different weightage parameters for all these 3 components of objective function. Rotation mixers utilize rotation Rx gates with angle parameters to alter qubit states, while Controlled Bit-Flip mixers utilize CNOT gates to avoid infeasible states, such as assigning two aircrafts to one route or allocating one route to two aircrafts.

Novelty of our approach is the mixers (Controlled bit-flip mixer) we used for feasibility of different constraints of given fleet allocation problem. Objective function includes aircraft operating costs, with less emphasis on demand fulfilment and greater focus on aircrafts utilization and on-time performance (no flight delays). We have done postprocessing of QAOA results to extract flights from routes and allocate aircraft to flights for each day, resulting in a full schedule. Key evaluation metrics involve aircraft costs, number of allocated flights, and deficit in seats (difference between forecasted and actual seats). These metrics are compared against an internal classical benchmark of BIP results.

III. Results & Conclusion

The results analysis indicates that 81.4% flights out of maximum possible allocations were successfully allocated with all flights being on time. Evaluation metrics such as number of allocated flights, number of empty flights, and aircrafts cost are consistent between Quantum and Classical approaches. However, Classical results outperform Quantum in the deficit in seats metric. This suggests that there's no advantage in solution quality or execution time when solving this problem using Quantum compared to Classical methods. Snapshot of results showing flights allocation to aircrafts is given below.

AircraftTail	Sequence	FlightNo	Origin	Destinatic	Initial Dep.	Initial Arri	Departure Date	Forecasted	NumSeats
G-AB	1	1157	LGW	EDI	600	800	27-11-2023	180	156
G-AB	2	1158	EDI	GLA	900	1115	27-11-2023	180	156
G-AB	3	1159	GLA	BHX	1230	1430	27-11-2023	200	156
G-AB	4	1160	BHX	GLA	1500	1730	27-11-2023	175	156
G-AB	5	1161	GLA	MAN	1800	2000	27-11-2023	186	156
G-AB	6	1162	MAN	LGW	2100	2350	27-11-2023	120	156
G-AC	1	1115	LTN	MAN	650	920	27-11-2023	150	156
G-AC	2	1116	MAN	LGW	1005	1240	27-11-2023	185	156
G-AC	3	1117	LGW	BHX	1350	1825	27-11-2023	200	156
G-AC	4	1118	BHX	LTN	1905	2320	27-11-2023	225	156

IV. Data & Code Availability

The Solution approach document, Final Defence presentation deck, Code base of our solution and Final test results of solution can be found on GitHub link: https://github.com/rbanerjee7/03360112/tree/main/Phase-2

References

[1] Unal, Yusuf & Sevkli et al. "A new approach to fleet assignment and aircraft routing problems". Transportation Research Procedia (2021).
[2] Vikstal, Pontus et al. "Applying the Quantum Approximate Optimization Algorithm to the Tail-Assignment Problem". Physical Review Applied (2019).