# Abstract

In the last few decades quantum computing has emerged as an alternate computing platform for achieving quantum supremacy. Practical quantum devices of moderate size are now within the reach of individuals due to the enormous progress made in technological realization. The theoretical advancements in devising quantum algorithms to gain quantum advantage yields schemes for finding faster solutions to various problems as compared to existing classical system. To execute these quantum algorithms on a real quantum computer, design tools for mapping quantum algorithms to a sequence of basic quantum gate operations efficiently has become very important. Also since the state-of-the-art quantum computing devices are imperfect, cost-effective techniques for noise mitigation is also crucial.

The present work addresses this design automation issue and consideration of error correction in low-resource environments. Towards this objective, the decomposition of an arbitrarily large *controlled-NOT* ($C^nNOT$) quantum operation using smaller quantum gates from well-known quantum gate libraries is explored. Several heuristics have been proposed for the decomposition that requires less run-time as compared to prior approaches. Next, a study of device-specific architectural constraints that exist in quantum computing platforms is presented. This is followed by discussions on constraint-aware mapping of quantum gate circuits to linear and generic $N$-dimensional qubit architectures, as well as two-dimensional IBM quantum processor. For linear architecture, the proposed scheme that uses gate look-ahead strategy is shown to require less additional gates to satisfy neighborhood constraints as compared to previous approaches. In another experiment, an analysis is conduced to show that additional gates required to satisfy the constraints can be reduced when degree of qubit association is increased. An approach for IBM quantum device architecture is also devised encompassing the selection of physical qubits, and determining initial and local permutations efficiently to obtain the final circuit. The experiments conducted demonstrate the effectiveness of the proposed heuristic approaches over prior state-of-the-art techniques. Finally, to carry out computation on encoded states that is an essential requirement for quantum fault tolerance, an extended set of coded operations based on $[[4, 2, 2]]$ encoding scheme is introduced, and the operational fidelity is demonstrated through experimental analysis.

**Keywords:** Quantum Circuit Compilation, Decomposition, Nearest Neighbor Mapping, Optimization, Fault-Tolerance