WMN joint link scheduling and routing problem

Kari Seppänen
Jorma Kilpi

VTT Technical Reseach Centre of Finland, Tekniikantie 21, Espoo, Finland

Kari.Seppanen@vtt.fi

Link scheduling problem in Wireless Mesh Networks (WMN) requires solving NP-hard Minimum Weighted Independent Set (MWIS). Furthermore, in multihop WMNs, the shortest path problem should be solved at the same time for optimal resource usage. While there exist heuristic algorithms to these problems [1,2], we propose a new problem formulation where the joint link scheduling and routing problem is transformed to finding shortest paths in a digraph that combines physical network topology to link schedule cycles into a "time-space" graph and allows QUBO formulation that may be solvable with hybrid quantum-classical algorithms.

To solve all upstream and downstream paths at the same time, we propose that the problem is turned into finding Steiner tree like in-trees and out-trees that respect the link scheduling constraints. We outline a new way to set Steiner tree constraints in digraph by relying solely on counting in-edges and out-edges for terminal and non-terminal vertices. The main advantage is to reduce the complexity from cubic to quadratic compared to earlier formulations [3]. We note that using our formulation can occasionally result in pseudo-forest and thus we propose an additional heuristic to transform certain parts of "time-space" graph to directed acyclic (sub-)graphs (DAG) and to adjust the weight of "time-edge" to reduce the probability of cycles.

Next, we transform the problem a QUBO formulation, in which we try to minimize the number of required qubits by applying Quantum Augmented Lagrangian (QAL) method [4] and some ad hoc penalty term formulation. By analysing the penalty terms, we show that we can omit one challenging constraint as other penalty terms already penalize the invalid combinations. Thus, we are able to construct QUBO formulation without any additional variables. Finally, we consider the possibilities to extend the proposed approach to handle Steiner tree problems in generic cases.

References

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[4] L. Cellini, A. Macaluso, and M. Lombardi, Scientific Reports, vol. 14, no. 1, (2024) p. 5142.

Figures

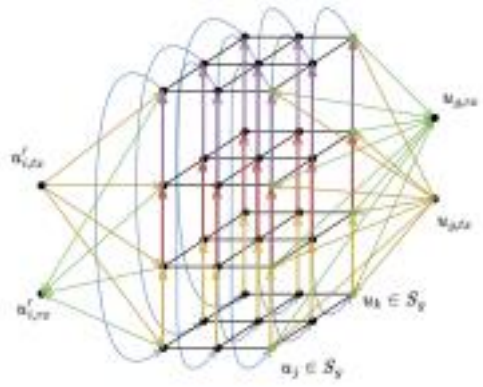

Figure 1: Joint link scheduling and routing problem modelled as "time-space" digraph, in which the problem reduces to shortest path problem.