Integer Linear Programming Formulation for Energy Efficient Mobility-aware Network Slicing in an Open Radio Access Network*

Lewiss QUARM[†a)], ***Student Member***, **Takanori HARA**[†b)], ***Member*, *and*** **Shoji KASAHARA**[†c)], ***Fellow***

1. Introduction

Open Radio Access Network (O-RAN) offers flexibility and cost savings through open interfaces and modular components [1]. On the other hand, *RAN Intelligent Controller* (RIC) optimizes resources via artificial intelligence (AI) driven *near-real time/non-real time RIC applications* (xApps/rApps) to improve quality of service (QoS), but increases energy consumption [1]. We formulate a mobility-aware network slicing problem as an *Integer Linear Program* (ILP) to minimize energy usage while supporting user mobility and service quality. Simulations show significant energy savings and high performance, particularly in dynamic mobility scenarios.

2. System Model

We consider two types of energy consumption costs for xApps/rApps: a running cost and a deployment cost. The running cost $C^t_{d,n}$ is defined as $C^t_{d,n} = (e_{\max} - e_{\mathrm{idle}})r^t_{d,n}/r_{\max} + e_{\mathrm{idle}}$, where $r^t_{d,n}$ is the CPU usage by slice $n \in \mathcal{N}$ in district $d \in \mathcal{D}$ at time t, and $r_{\max}$ is the total available CPU resource. Let $\mathcal{N}$ and $\mathcal{D}$ be sets of slices and districts, respectively. $e_{\max}$ and e_{idle} represent the peak and idle energy costs. The deployment cost is a fixed value $\tilde{C}$ [2].

The objective is to minimize the total energy consumption of the O-RAN system while meeting the service level agreement (SLA) for each service. The objective function of the proposed ILP is defined as $\min \sum_{t=1}^{T} \sum_{d\in\mathcal{D}} \sum_{n\in\mathcal{N}} (\alpha^t_{d,n} C^t_{d,n} + \alpha^t_{d,n}(1-\alpha^{t-1}_{d,n})\tilde{C})$, where $\alpha^t_{d,n} \in \{0,1\}$ are binary decision variables. The constraints ensure SLA compliance: the throughput $Z^t_{n,k}$ must meet the minimum requirement $Z^t_{n,k,\min}$, and the delay, defined as $F^t_{n,k}/Z^t_{n,k}$, must hold the maximum delay $D_{n,k,\max}$. Finally, the total CPU resource usage across all slices in district d must not exceed the available capacity, $r_{\max}$. This balances energy efficiency with maintaining required service quality.

[†]The authors are with the Division of Information Science, Nara Institute of Science and Technology, Nara, 630-0192 Japan.

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a) E-mail: qurqm.lewiss.qn1@is.naist.jp
b) E-mail: hara@ieee.org
c) E-mail: kasahara@ieee.org

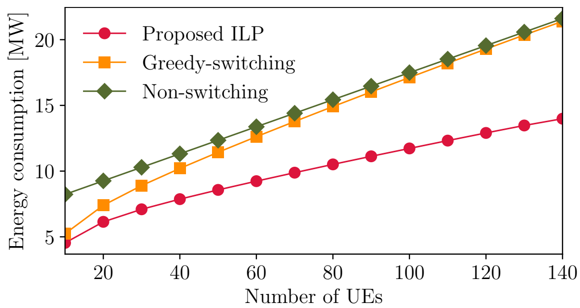

Fig. 1 Energy consumption among the three methods.

3. Simulation

We consider a downlink scenario where UEs move freely across several adjacent hexagonal regions, requesting a single service throughout $T = 1000$. We compare energy consumption across three methods: the proposed ILP, non-switching (slice stays active throughout T), and greedy-switching (slice activates on request and deactivates when no demand). The evaluation metric is average energy consumption from 100 trials. Figure 1 shows that energy consumption increases as the number K of UEs grows. However, the ILP consistently delivers the lowest energy consumption, reducing it by up to 31% and 27% compared to non-switching and greedy-switching, respectively, when $K = 50$, while meeting SLA requirements.

4. Conclusion

In this paper, we formulated a mobility-aware network slicing problem as an ILP to minimize energy consumption of RIC applications while meeting SLAs in the O-RAN system. Simulations showed the proposed ILP outperforms both baseline methods in reducing energy consumption.

References

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