Benchmarking and Neural Network-Based Surrogate Model for Hybrid Online-Offline Evolution of Service Function Chain Embedding

Service Function Chains (SFCs) virtualise network functions, such as firewalls, enabling them to be programmatically embedded on physical servers and linked together using Software Defined Networking (SDN) to create a virtual service overlay over the physical substrate network. This offers several benefits, such as network programmability and reduced capital and operational expenditures. Optimally embedding SFCs on the physical network is an actively researched NP-hard optimisation problem.

Genetic Algorithms (GAs), which are meta-heuristic algorithms, have been used in the literature to optimally embed SFCs. GAs generate random candidate solutions, evaluate their fitness, select the best candidates, and iteratively improve them to produce an optimal SFC embedding. Existing GA-based approaches mostly evaluate the fitness of candidate solutions offline using mathematical models. The online approach evaluates fitness on an SFC emulator. Offline evaluations are faster, but their accuracy has not been established by experimental evidence in the literature. Online evaluations are accurate but slower.

We propose a hybrid online-offline evolution using a benchmarking and Neural Network (NN)-based surrogate model called BENNS for faster and more accurate offline evaluation of traffic latency based on experimental data generated on the SFC emulator. Unlike the mathematical models used in the literature for other offline evaluations, BENNS uses benchmarking models and NNs trained on experimental data to predict the fitness of candidate solutions, providing a reliable fitness evaluation. We use BENNS to perform offline fitness evaluations until a user-specified threshold is met, after which we perform online evaluation on the SFC emulator to verify fitness.

We experimentally evaluate the hybrid approach across five different static network scenarios and a dynamic scenario and compare its performance with online-only and offline-only GA approaches. The results demonstrate that the BENNS-based hybrid approach generates an optimal SFC embedding within 19.1 minutes on average in all static scenarios, while the online-only and offline-only approaches failed to converge in any scenario, taking an average of 17.8 hours and 10.97 hours. The mean absolute difference between the traffic latency predicted by BENNS and measured on the SFC emulator was 1 ms, while for the mathematical model used by the offline-only approach, it was 305.72 ms, demonstrating BENNS's better accuracy.

BENNS is a significant first step in my ongoing effort to use GAs to optimally embed SFCs. BENNS is complete with experimental results and is ready for use, but I would also like to receive feedback on my overall project of using GAs to optimally embed SFCs.