Deep Reinforcement Learning for Dynamic Reliability Aware NFV-Based Service Provisioning

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December 12, 2019

OUTLINE

- Introduction
- Related works and Motivations
- System Model
- Deep Reinforcement Learning (Deep-RL) Model
- Numerical Results
- Conclusion

Introduction

INTRODUCTION

- Service deployment in traditional enterprise networks tightly depends on:
  - Specific hardware named middlebox
- Examples of such middleboxes are:
  - Quality of service (QoS) monitoring tools
  - Intrusion detection systems
  - Deep packet inspection

What is network function virtualization

- Hardware implementation of network functions:
  - Limits the expansion of the networks.
  - Increases CAPEX and OPEX.
- Network Function Virtualization (NFV) is promising to obviate these limitations.
- In NFV-based networks:
  - The hardware middleboxes replaced by the modules of software named virtual network functions (VNFs).
  - These software programs are running on commodity servers.

Service definition in network function virtualization

- To provide a service in NFV-based networks:
  - A set of appropriate VNFs should be sequenced.
  - This chain of VNF called service function chain (SFC).
- Service placement or NFV placement is:
  - The procedure of assigning resources of the network infrastructure to the VNFs of service.
- Service placement is the most challenging task in NFV-based networks.

Related works and Motivations

Related Work

The game theoretical model for service placement: A dynamic market mechanism design for on-demand SFC provisioning and pricing in the NFV market.

- [1] S. Gu and et. al., "An efficient auction mechanism for service chains in the NFV market," in Proc. of *IEEE INFOCOM*, San Fransisco, CA, May. 2016.
- [2] X. Zhang and et. al., "Online stochastic buy-sell mechanism for VNF chains in the NFV market," *IEEE Journal on Selected Areas in Communications*, vol. 35, no. 2, pp. 392â406, 2017.

Machine Learning approaches have been used recently in NFV: An efficient online algorithm for dynamic service placement.

- [3] Y. Jia and et. al., "Online scaling of NFV service chains across geo-distributed datacenters," *IEEE/ACM Trans. on Networking (TON)*, vol. 26, no. 2, pp. 699â710, 2018.
- [4] V. Sciancalepore and et. al., "z-TORCH: An automated NFV orchestration and monitoring solution," *IEEE Trans. on Network and Service Management*, vol. 15, no. 4, pp. 1292-1306, 2018.

Motivations

- Service placement considering the requested service level agreement (SLA) of the service is a major challenge in network slicing.
  - Reliability requirement and end to end delay are examples of such SLAs.
- Due to software implementation of network functions in NFV, reliability has become more important.
- Due to dynamicity of the services, dynamic service placement should be considered.
- Dynamic reliability aware service placement is missing in NFV literature.
- We introduce a novel model based on Deep reinforcement learning (Deep-RL) for dynamic reliability aware service placement.

System Model

NETWORK INFRASTRUCTURE

- There are three main components for the NFV based network:
  - Services requested by the users and has a specific reliability requirement.
  - Infrastructure network provider (InP) is the owner of the commodity servers and the networking infrastructure between them.
  - Network operator (NO) is responsible for responding incoming service using the InP's resources.
- There are multiple InPs where each one provide number of servers for NO.
  - The main characteristic of each InP is the failure probability of its servers.
  - The unit cost of using servers of each InP is dependent on the failure probability of its servers.
- $S = \{S_i^m\}$ is the set of servers (S_i^m is the m^{th} server in i^{th}).
- $L = \{L_{ij}^{mh}\}$ is the set of links between the servers.

TIME EVOLUTION AND SERVICE CHARACTERISTICS

- We divide the time into equal length slots:
  - Service placement is performed at the beginning of each slot for incoming services during previous slot.
  - It is possible that some of incoming services is not admitted due to resource scarcity.
  - Each admitted service lasts for a random number of slots
- There are L service types:
  - K_l it the number of incoming services of l^{th} type in each slot.
  - U_l is the number of VNFs in l^{th} type's SFC.
  - r_l^u is the required resource of u^{th} VNF of l^{th} type's.
  - d_l is the departure probability of l^{th} type.
  - F_l is the maximum tolerable failure probability of l^{th} type.
  - The decision variable of placing the u^{th} VNF of the $(k_l)^{\text{th}}$ service of l^{th} type in the m^{th} server of the i^{th} InP in the n^{th} slot is $x_{n,i,k_l}^{m,u} \in \{0, 1\}$.

Service Placement Policy

- The NO aims to maximize the number of admitted service while minimizing the placement cost.
- The two main components of the placement cost are:
  - Server cost in each slot indicated by ξ_n^s.
  - Link cost in each slot indicated by ξ_n^l.
- There are some constraints for performing service placement in each slot:
  - The reliability of each service which is a function of $x_{n,i,k_l}^{m,u}$.
  - The resource capacity of each server.
  - The bandwidth limitation of each link.
- The initial optimization problem is intractable due to dynamic nature of the variables.

Deep Reinforcement Learning (Deep-RL) Model

Deep-RL Model

- Due to the dynamic nature of service placement problem, learning based techniques can be helpful.
- The goal of the learning technique is:
  - learning a policy determines what action to take in each state.
- In service placement problem, the learning agent should learn how many and what service types can admitted in each slot in order to
  - Maximize the number of admitted services.
  - Minimize the placement cost.

Learning necessity for Service Placement

- In reinforcement learning (RL), there are one or more agents who explore and exploit the environment based on:
  - The reward gained directly from an environment.
  - The state which completely encapsulate all features and conditions.
- A particular policy is used to make a balance between the exploration and the exploitation.
- In large environments where states are covering a wide range of possibilities, RL has some weaknesses.

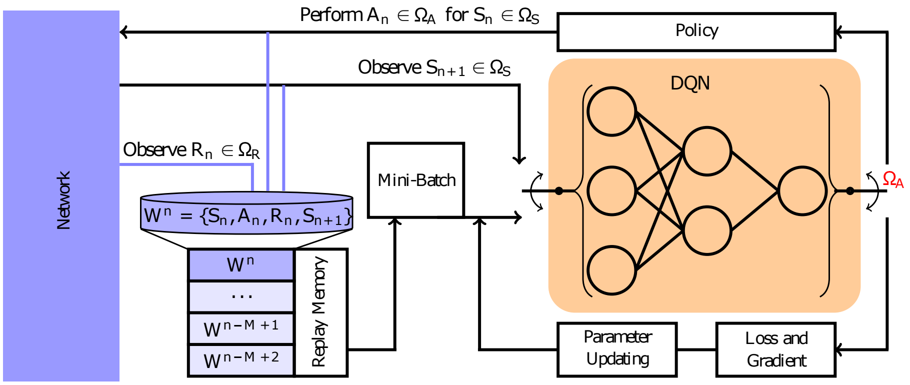
Deep-RL Model for Service Placement

- A four-tuple $(\Omega_S, \Omega_A, \Omega_R, \Omega_M)$ should determined where:
  - Ω_S is the state set.
  - Ω_A is the action set.
  - Ω_R is the reward set.
  - Ω_M is the memory set.
- The state in service placement problem is defined as:
  - Available resources provided by InPs.
  - Resources demanded by a service.
  - Requested reliability of each service.
- We define the action as the possible placement policies for each incoming service.

Deep-RL Model for Service Placement

- The reward of Deep-RL agent for service placement defined based on:
  - A penalty for a situation in which the reliability requirement is not satisfied.
  - A reward for the successful placement of a service.
  - A penalty for situations in which resource allocation is failed due to the lack of enough resource in the selected server.
  - Placement cost of each service.
- The memory set of Deep-RL agent is defined based on:
  - Current state.
  - Taken action.
  - Gained reward.
  - Next state.

An Overview of Deep-RL



Numerical Results

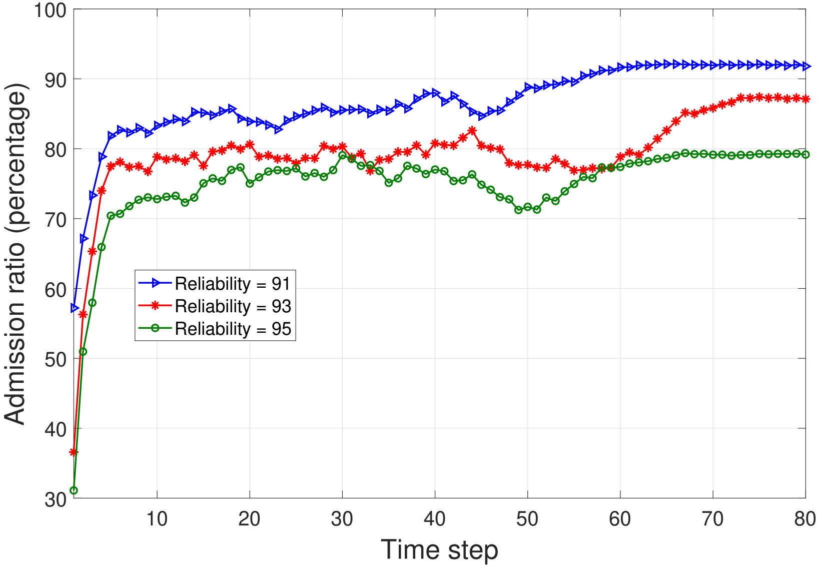
Simulation Setup

- We use Keras and TensorFlow in Python for simulation.
- We consider five InPs with different reliabilities $\{96, 97, 98, 99, 99.9\}$.
- Each InP has five servers with the same reliability level
- Each server has capacity of 100 units of one resource type.
- The reliability of the services is among $\{91, 92, 93, 94, 95\}$.
- The number of VNFs in each service type is between three to five VNFs.
- The resource demand of the VNFs is considered to be between 10 and 20 units.
- The departure probability for all service types is equal and between 0.5 to 0.8

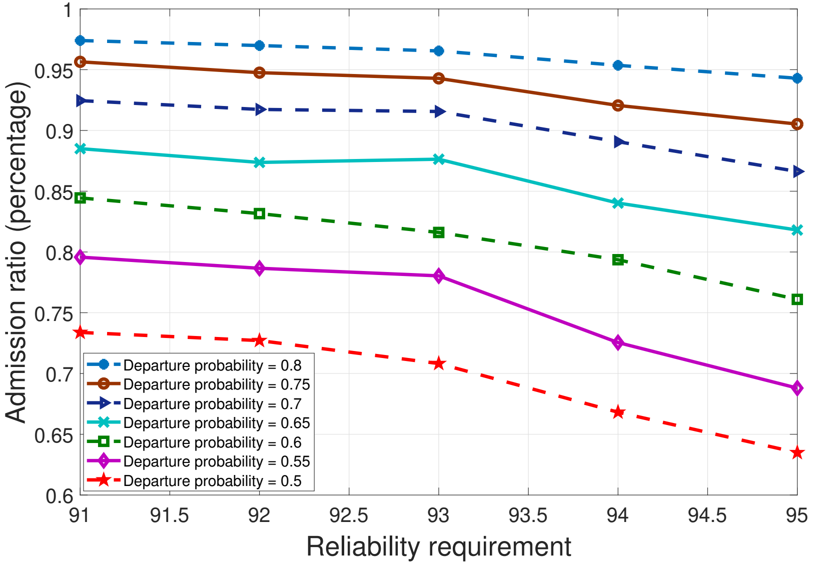
Simulation Setup

- We use a fully connected Deep neural network (DNN) includes:
  - Hyperbolic tangent and ReLu as the activation function in the middle layer.
  - The output layer is connected to a linear activation function.
- Each layer is associated with Dropout, with its parameter set between 0.05 and 0.2, to avoid overfitting.
- The mean square error metric for the error function.

Admission ratio for different service type through the learning.



Admission ratio for different service types under various departure probability



Conclusions

Conclusions

- NFV is a promising paradigm shift for next generation of telecommunication network.
- Service placement is referred to allocation of InP's resources to incoming services.
- Service placement considering the dynamicity of services and their SLA is a major challenge in NFV-based network.
- We introduced a Deep-RL model for dynamic reliability-aware service placement for:
  - Maximizing the number of admitted services.
  - Minimizing the placement cost.

Thank You!