

# Time Varying Resource Allocation in Network Function Virtualization

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## Abstract

With the spread of leasing resources from cloud/datacenters infrastructures, several tenants are deploying their services on these sharing architectures based on technologies of NFV. However, existing solutions of resource sharing mechanisms do not consider time-varying sharing when allocating resources, which only consider computing and network resources. In this paper, we focus on finding a heuristic algorithm to solve the NP-hard time-varying resource sharing problem in NFV network. Compared to the baseline approach, our method can reduce by 28.7% amount of overprovisioning resource.

## 1. Introduction

Recently, network providers are accounting on adopting new technologies of network function virtualization (NFV) and Software-Defined Networking (SDN) on their infrastructures. Especially, with the spread of Cloud Computing, these virtual techniques are highly used in datacenter networks to improve flexible and efficient management by sharing physical network devices between multiple tenant networks. Several network providers adopt new technologies of NFV and SDN in their infrastructures of networks. It can reduce significantly the capital expenditure and operating expenses [1].

In the virtualization environment, an infrastructure provider (InP) owns a substrate network (SN), including a set of physical nodes and links, one service provider, who leases that physical network resources from such an InP and creates customer virtual networks to provide services, such as video streaming, VoIP. SDN currently has considered as the promising solutions due to their programmable capacity and flexibility for creating dynamic and separate virtual networks on top of physical network infrastructure [1,2].

In this paper, we focus on resource sharing problem in virtual network, where in the micro-level time, a single substrate network provider has to schedule for sharing resources in a physical node that is hosting multiple virtual nodes, and in a physical link that is embedding multiple virtual links. The problem becomes complicated due to the service provider cannot predict the number of end users of the applications deployed in their virtual networks [3]. Traditionally, by fixed overprovisioning

substrate resources for virtual network functions (VNFs) [4], it is clearly wasteful to deploy network services. For the purpose of analysis, we assume that the operation of substrate network is based the time-division-multiplexing, i.e., the time period is divided into multiple slots of equal length. We propose the mechanism that can share substrate resources to multiple virtual network services of multi tenants in terms of reducing the number of time slots used.

The rest of this paper is organized as follows: Section 2 presents the network model and problem formulation. Section 3 presents the proposed algorithm. The simulations and numerical results are shown in Section 4. Finally, we conclude the paper in Section 5.

## 2. The time-varying resource sharing problem

We consider a substrate network that supports for multiple tenants with a set  $N^s$  of substrate nodes and a set  $E^s$  of physical links. We model the substrate network as a weighted undirected graph,  $G^s = (N^s, E^s)$ , where each node  $n^s \in N^s$  has a CPU capacity of resource  $C(n^s)$ , and each link  $e^s(n_i^s, n_j^s)$  has a bandwidth capacity  $B(e^s)$  in time slots. Based on the capacity of the substrate network, many tenants lease resources on this network and deploy their network services. We consider a set of virtual network  $W^v$ . Each virtual network  $w_i^v \in W^v$  is mapped on the physical network as follows:  $M: w_i^v \rightarrow G^s$ , where the set  $N_i^v$  of virtual nodes of virtual network  $i$  is mapped on  $N^s$ , and the set  $E_i^v$  of virtual links of virtual network  $i$  is mapped on  $E^s$ , such that the required resources of virtual nodes do not exceed the hosting physical node. It is similar on the physical link, where the capacity of required virtual links

is less than the physical link.

In this paper, we model the time-varying resource requirement of each virtual node and link is composed based on the base requirement  $b(n_i^v)$  and varying requirement  $\alpha(n_i^v)$  with a probability  $p(n_i^v)$ . For example,

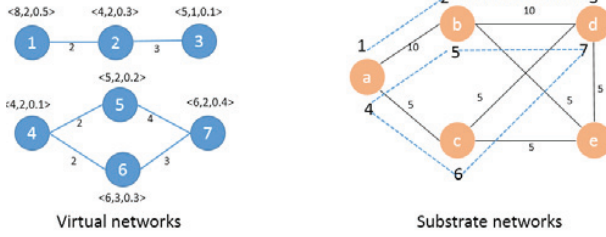


Fig. 1: An example of virtual network embedding with time-slot requirement.

in Fig. 1, virtual node 1 required 8 basic time slots and 2 varying time slots with probability 0.5. Similarly, we have the tuple that is used to represent the time slot requirement of virtual link  $e_i^v$  as follows  $\langle b(e_i^v), \alpha(e_i^v), p(e_i^v) \rangle$ .

Overall of notations, we can formulate the objective of the embedding problem as follows

$$\min S = \sum_{w_i^v \in W^v} \left[ \sum_{n_k^v \in N_i^v} x_{i,k} p_{t,k} + (b_k^v(n_k^v) + p(n_k^v) \alpha_k^v(n_k^v)) + \sum_{e_k^v \in E_i^v} y_{i,k} p_{t,k} + (b_k^v(e_k^v) + p(e_k^v) \alpha_k^v(e_k^v)) \right] T_i^v$$

The meaning of the objective function is to minimize the total assigned time slots when deploying the set of  $W^v$  virtual networks, and  $T_i^v$  is the lifetime of network service  $i$ ,  $x_{i,k}$  is the binary variable to indicate that physical node  $i$  is hosting virtual node  $k$ .

This resource sharing problem can be seen as the bin packing problem, where we pack multiple items into minimum number of bins. In our problem, VNFs can be seen as items and physical nodes can be seen as bins. Hence, this problem is NP-hard, which cannot find the solution in polynomial time. To address this problem, we propose the heuristic algorithm in the next section.

### 3. Time-varying resource allocation algorithm

In this paper, we assume that virtual networks arrive sequentially. Then, the network operator can serve those virtual networks underlying in an operation queue with FCFS policy.

As shown in Algorithm 1, the controller will pick one-by-one virtual network then will place in to a set of available nodes. Before that, all physical nodes that

cannot host any nodes of the arrived virtual networks will not be considered. To choose the sub set of hosting nodes, the controller tries to minimize the total processing time

$$S_i^v = \left[ \sum_{n_k^v \in N_i^v} x_{i,k} p_{t,k} + (b_k^v(n_k^v) + p(n_k^v) \alpha_k^v(n_k^v)) + \sum_{e_k^v \in E_i^v} y_{i,k} p_{t,k} + (b_k^v(e_k^v) + p(e_k^v) \alpha_k^v(e_k^v)) \right] T_i^v$$

#### Algorithm 1 Heuristic algorithm for time-varying resource sharing problem

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Waiting until a virtual network  $w_i^v$  arrives;
for  $n_i^s \in N^s$  do
    Checking the available resource of  $n_i^s$ ;
    Finding a set of nodes that can minimize  $S_i^v$ ;
end for
Placing  $w_i^v$  to the chosen set;
    
```

### 4. Numerical results

In this part, we represent the simulation result of our algorithm, with 20 nodes as shown in Fig. 2. We make the simulation with five groups of network services that include from 10 VNFs to 50 VNFs.

To show the efficiency of our proposed method, we compare to the baseline, which only places VNFs based on considering CPU and memory resources. Without accounting the lifetime and processing time requirement, Baseline shows overprovisioning allocation by 28.7% compared to our proposed method as shown in Fig. 3.

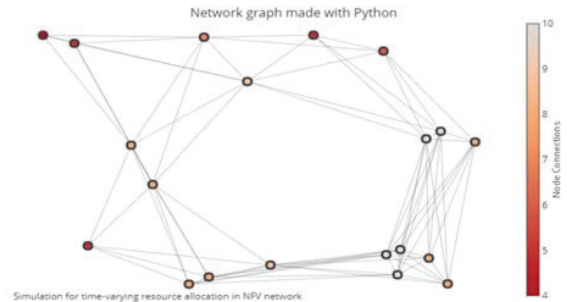


Fig. 2: The substrate network.

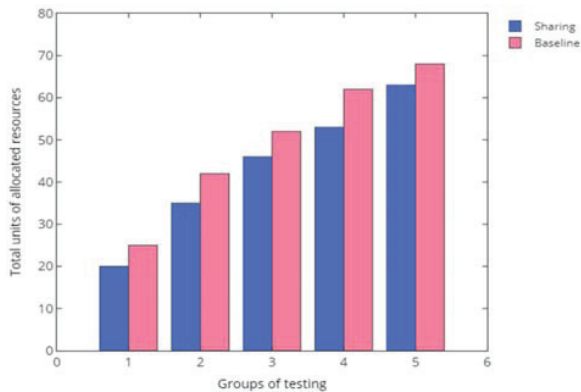


Fig. 3: Comparison of resource used.

In this paper, we consider the time-varying resource sharing problem, which cannot solve in polynomial time. We formulate the problem and propose a heuristic algorithm to solve it. In particular, to find the solution, we design a queue that is used to place virtual networks in terms of minimizing assigned time slots. We conduct our algorithm based on the simulation results and compare to the baseline approach. The result shows that our approach can improve significantly in total assigned resource units. The analysis and simulation show that our proposed system is adaptable and can be applied in NFV architectures.

#### Acknowledgement

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government(MSIT) (NRF- 2017R1A2A2A05000995).

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