Demand-adaptive VNF placement and scheduling in optical datacenter networks

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8/10/2018

Group Meeting Presentation

Background

- High CAPEX and OPEX when deploying and updating network infrastructure, due to the need of specified network hardware (middle-boxes).

- Middle-box suffers several shortcomings:
  i. they are expensive
  ii. require specialized managing personnel
  iii. have high energy costs
  iv. do not allow to add new functionality
  v. have short lifecycles

- The number of middleboxes is comparable with the number of routers and switches needed to maintain the operation of the network.

Background

Advantages of Network Function Virtualization (NFV):

- can be customized on-demand
- have flexible options of their locations
- can be provisioned dynamically and elastically
- enable re-configuration at runtime
- …

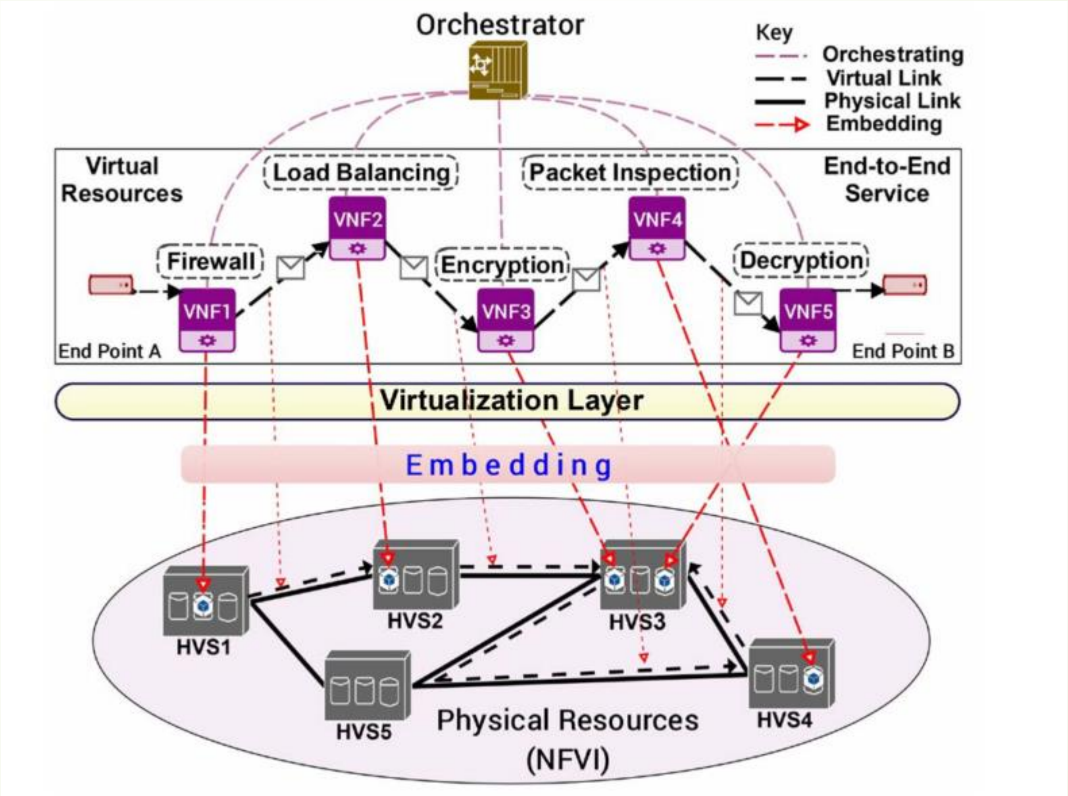
Several issues need to be considered before provisioning a service function chain (SFC) [1]

- the cost of deploying a new VNF
- energy cost for running a VNF
- the cost of forwarding traffic to and from a VNF
- fragmentation of the underlying physical resource pool

[1] Md. Faizul Bari, et al, "Orchestrating Virtualized Network Functions," in Proc. 2016 IEEE Trans. On Network and Service Management, vol. 13, no. 4, pp. 725-739, 2016.

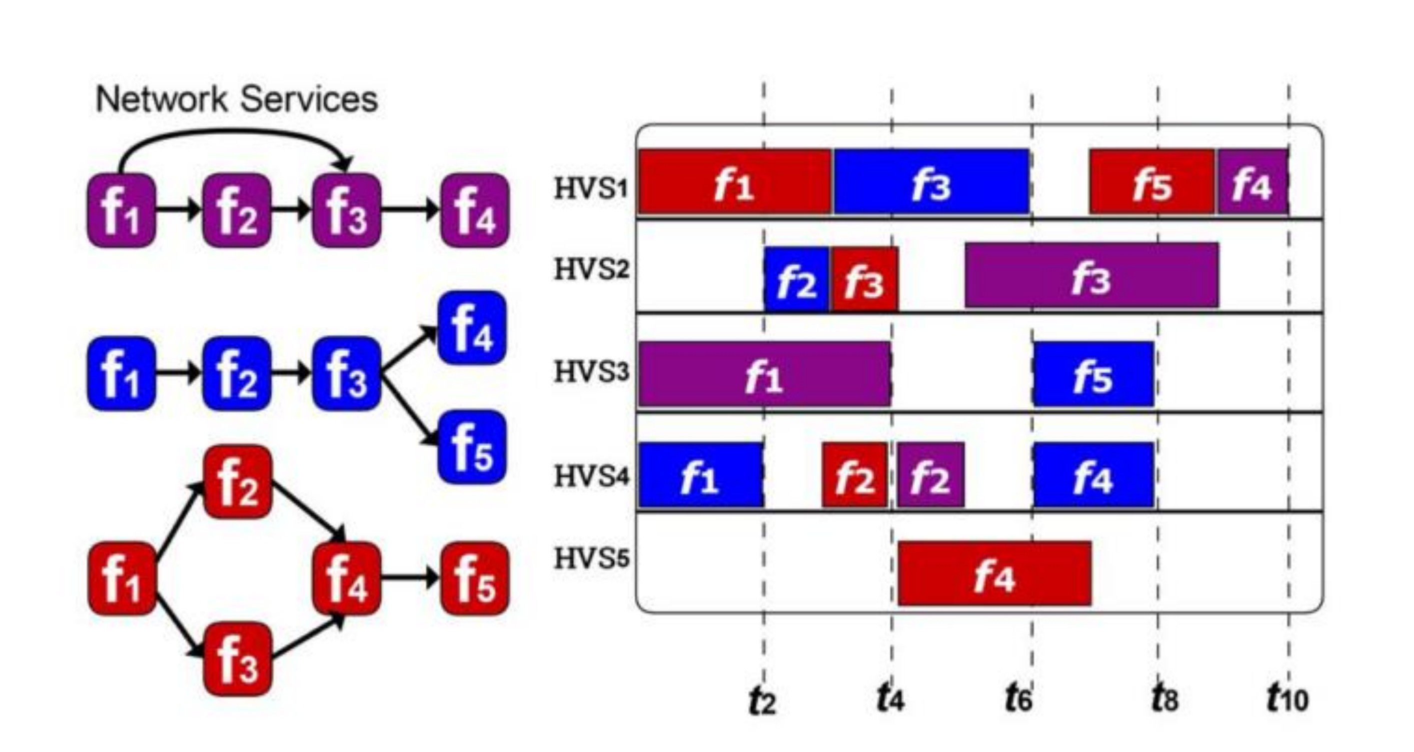
Background

VNF Placement: Seeks to find where to allocate the VNFs in the network infrastructure in a suitable way, considering a set of requested network services.



Background

VNFs Scheduling: A proper scheduling of VNFs' execution should be performed in order to minimize the total execution time of the network services, and thus obtain improved performance.



Background

Different kinds of latency when placing and scheduling VNFs

Type	Latency
VM boot time	Several seconds [1]
VNF installation time	Tens of milliseconds ~ several seconds [1]
Transmission latency	Based on the transmission rate
Processing time	Based on the capacity of VNF and data size
Instance removing time	Several milliseconds

Application	Throughput		
	1 Gbps	5 Gbps	10 Gbps
NAT	1 CPU	1 CPU	2 CPUs
IPsec VPN	1 CPU	2 CPUs	4 CPUs
Traffic Shaper	1 CPU	8 CPUs	16 CPUs

[1] A. Sheoran, et al, "An Empirical Case for Container-driven Fine-grained VNF Resource Flexing," in Proc. 2016 IEEE Conference on Network Function Virtualization and Software Defined Networks, NFV-SDN, 2016.
[2] Abhishek Gupta, M. Farhan Habib, Uttam Mandal, Pulak Chowdhury, Massimo Tornatore, Biswanath Mukherjee, "On service-chaining strategies using Virtual Network Functions in operator networks," Computer Networks, vol. 133, pp. 1-16, 2018.

Problem and Challenge

To reduce the latency and operation cost (e.g., installation/uninstallation):

- ❖ Where to place and how to schedule these VNFs?
  - ➢ Have an effect on the computing resource usage
  - ➢ Different locations to host the VNFs have different latency (transmission latency and propagation latency)
  - ➢ Also affect the spectrum resource consumption

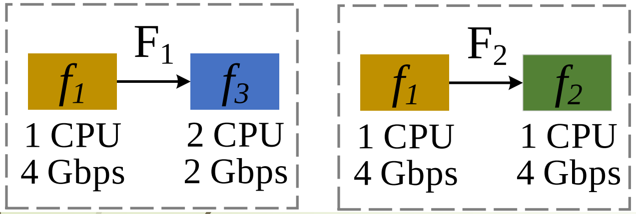
- ❖ If we an instance of a VNF can be keep in an idle state for a period of time, how long should this period be?
  - ➢ Longer duration of idle state may increase CPU cost

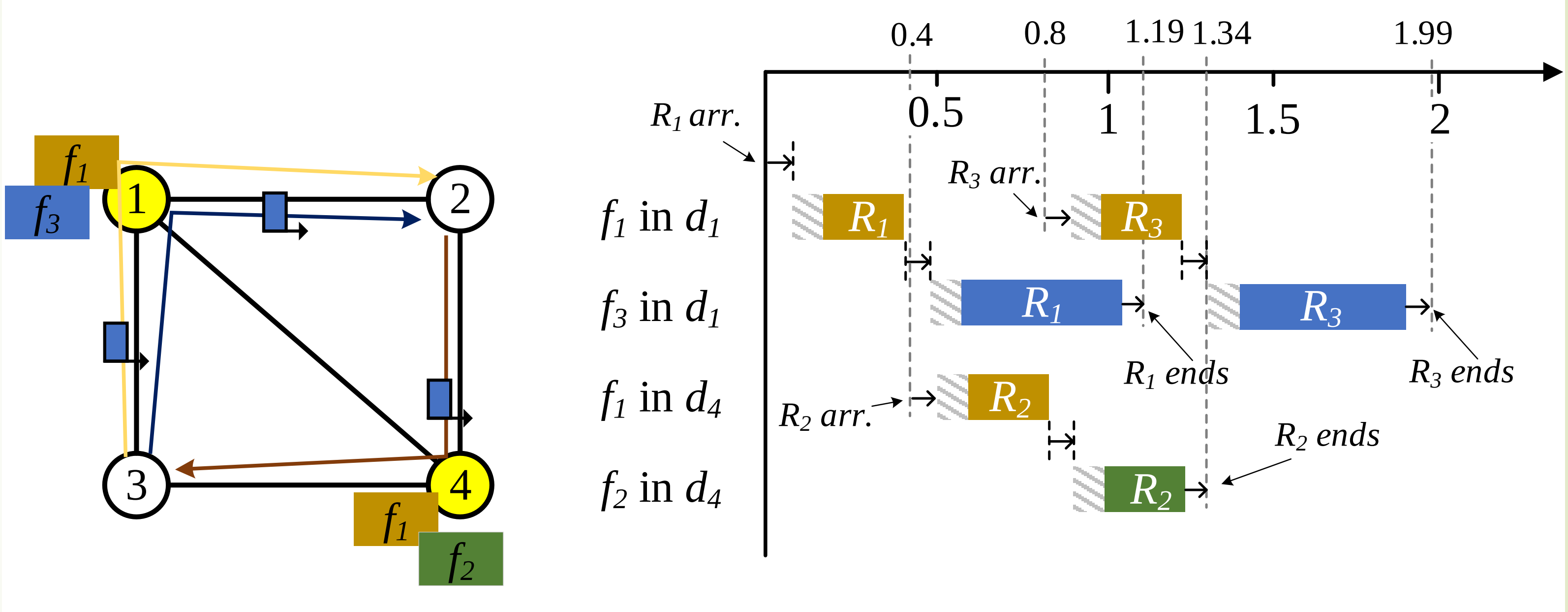
- ❖ The duration for each VNF should be the same?
  - ➢ Some kinds of VNF are more popular

CASE 1

Problem and Challenge

$R_1(3, 2, F_1, 1G, 1.2s)$ →
$R_2(2, 3, F_2, 1G, 1.2s)$ →
$R_3(3, 2, F_1, 1G, 1.2s)$ →





(a)

VNF Installation Time

VNF Processing Time

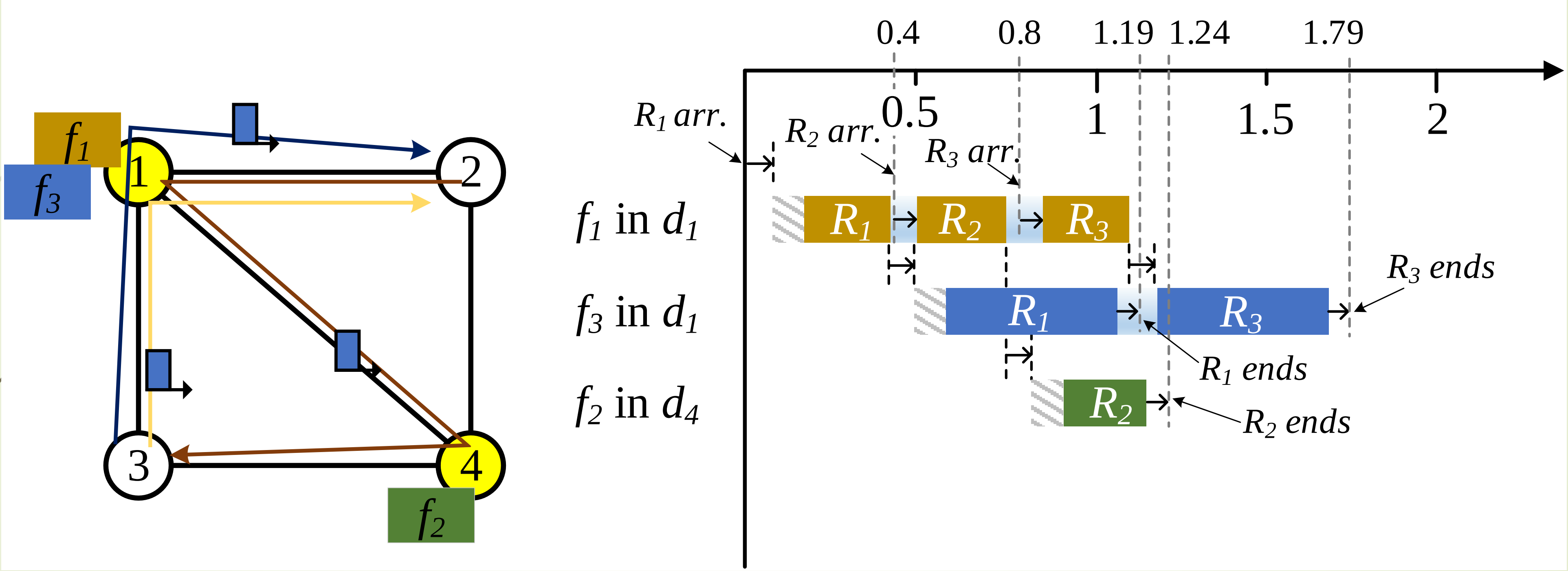
VNF Idle State Duration

→ Transmission Latency

* *Transmission rate per subcarrier is 12.5 Gbps with BPSK employed*

CASE 2

Problem and Challenge



VNF Installation Time

VNF Processing Time

VNF Idle State Duration

→ Transmission Latency

CASE 2

Performance Comparison Between Two Schemes

Request	*Ins. Lat.*	*Trans. Lat.*	*Process Lat.*	*Total Lat.*	*Gap*
R_2-DNA	0.1×2	0.08×3	0.25+0.25	0.94	12%
R_2-DA	0.1	0.08×3	0.25+0.25	0.84	
R_3-DNA	0.1×2	0.08×3	0.25+0.5	1.19	17%
R_3-DA	0	0.08×3	0.25+0.5	0.99	

Problem Statement

- Given:
  - Datacenter network topology
  - Set of VNFs
  - Set of service function chains
  - Set of use requests

- Objective:
  - Reduce the network resource consumption and latency at a reasonable cost of computing resource

- Constraints:
  - Latency requirement
    - Processing latency ⬄ data size, VNF throughput, installation time, and idle time
    - Transmission latency ⬄ link capacity, data size
    - Propagation latency ⬄ distance

Solution

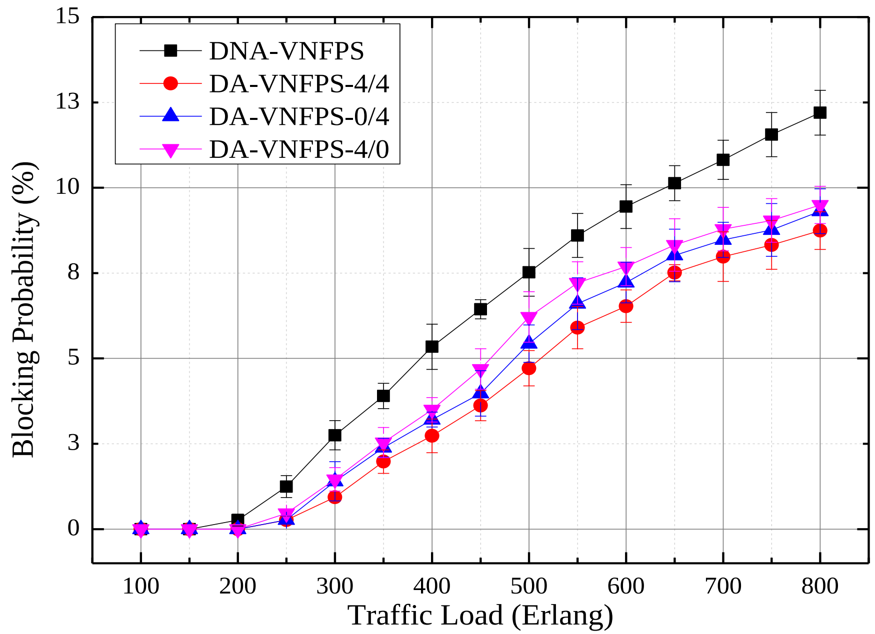
- Idle state duration calculate:

$$l_f = t_{base} + t_{scale} \cdot \frac{v_f}{v_{total}}, f \in T$$

l_f denotes the duration value of the idle state for VNF f, t_{base} denotes the lower bound of the idle state duration, and t_{scale} denotes the scale of the idle state duration, v_f denotes the times of VNF f is requested in the network, and v_{total} denotes the total times that all VNFs are requested.

- Key points of the algorithm:
  - Try to place the VNF in a datacenter close to the source node or the location where prior VNF is located, then propagation latency can be reduced
  - After each SFC request is served, the idle state duration of each used VNF is calculated and updated

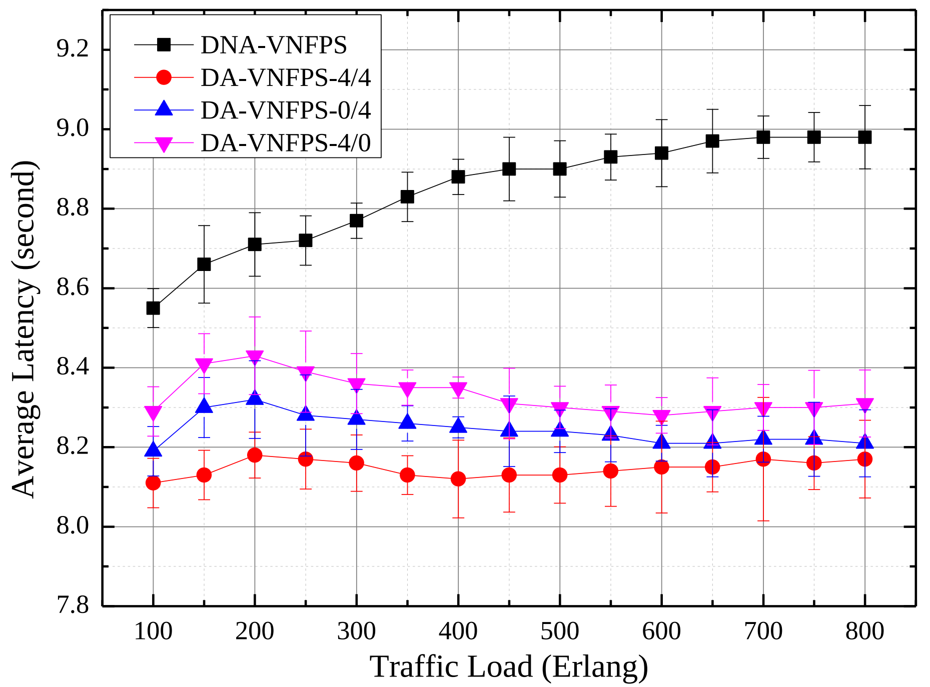
Blocking Probability



(a)

- ✓ DA-VNFPS-4/4 reduces BP by over 28% at the traffic load of 800 Erlang than DNA-VNFPS.
- ✓ The DA-VNFPS-0/4 and DA-VNFPS-4/0 schemes achieve a little higher BP compared with the DA-VNFPS-4/4 scheme, which means a longer duration of the idle state can help to improve the BP performance.

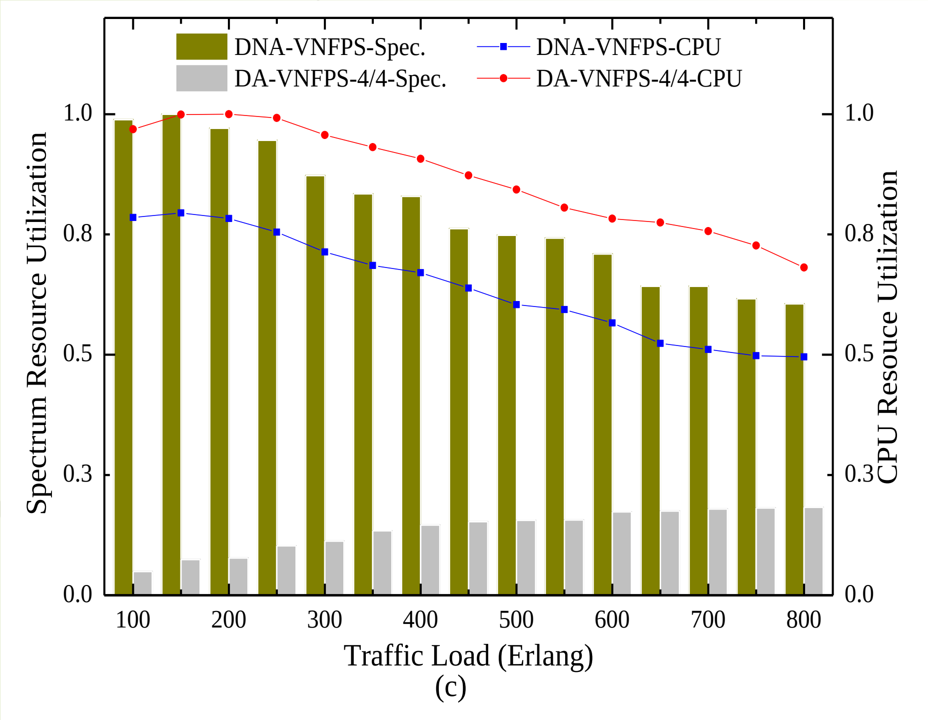
Average Latency



(b)

- ✓ The reduction between DA-VNFPS-4/4 and DNA-VNFPS can reach as high as 10%.
- ✓ Also, with different values of t_{base} and t_{scale}, DA-VNFPS achieves close results. However, DA-VNFPS-0/4 achieves lower average latency compared with DA-VNFPS-4/0.

Resource Utilization



- ✓ With the increase of traffic load, both CPU and spectrum resource consumption reduce for DNA-VNFPS, because more user demands are blocked at high traffic load.
- ✓ DA-VNFPS reduces the spectrum resource consumption significantly but has a slight higher CPU resource consumption than DNA-VNFPS.

Other results

- Link capacity has an important effect on the VNF placement:
  - If it has a similar value to the throughput of a VNF, it prefers to use the VNFs in the same location
- The installation time of a VNF instance and the boot time of a VM directly affect the VNF placement:
  - If don't consider these latency, each VNF in a SFC request will use a new VM
- The size of user data also affects network performance:
  - Large data can weaken the advantage of the idle state
  - Small data can leads to high blocking probability

Thanks!