Finding the Optimal Reconfiguration for Network Function Virtualization Orchestration with Time-varied Workload

Satyajit Padhy, Jerry Chou
National Tsing Hua University

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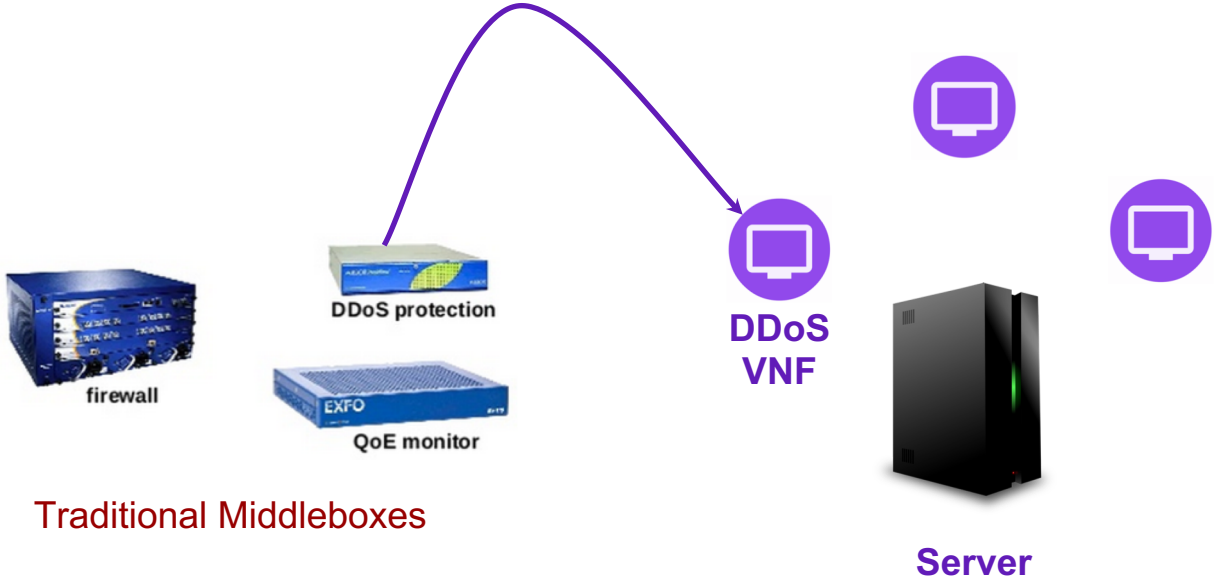
Outline

1. Background
2. VNF Placement Problem
    a. Approaches
3. VNF Reconfiguration Problem
    a. Problem Definition
4. Objective & Approach
5. Results

Introducing NFV (Softwarizing Middleboxes)



Traditional Middleboxes

- Less CAPEX/OPEX
- More Flexibility
- No-Fixed Location
- Introduce new services to the network seamlessly
- Better resource and energy utilization
- For the Future (5G, SDN)

** NFV=Network Function Virtualization, VNF= Virtual Network Function

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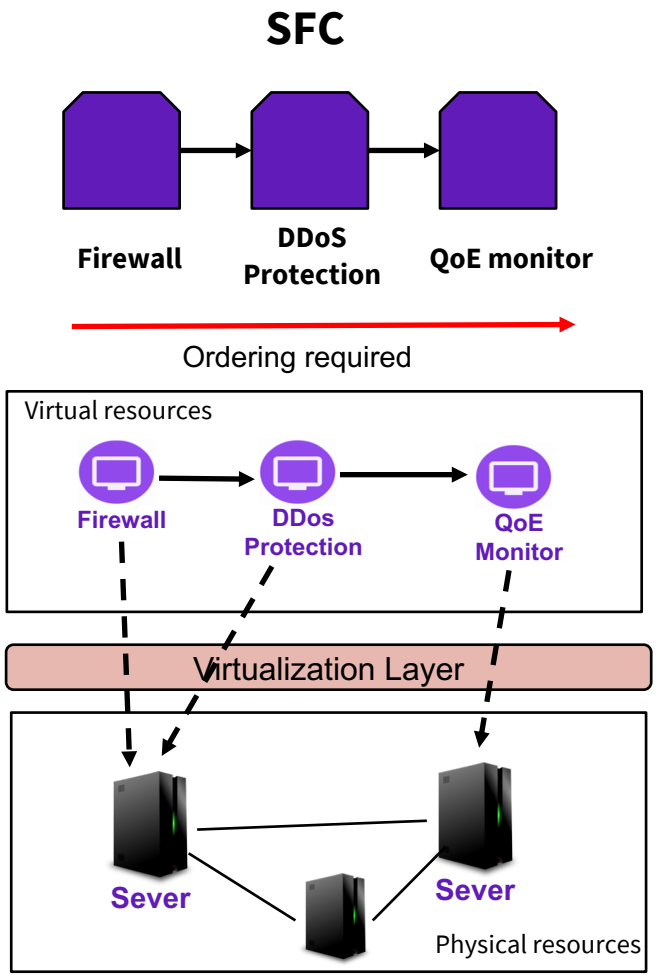
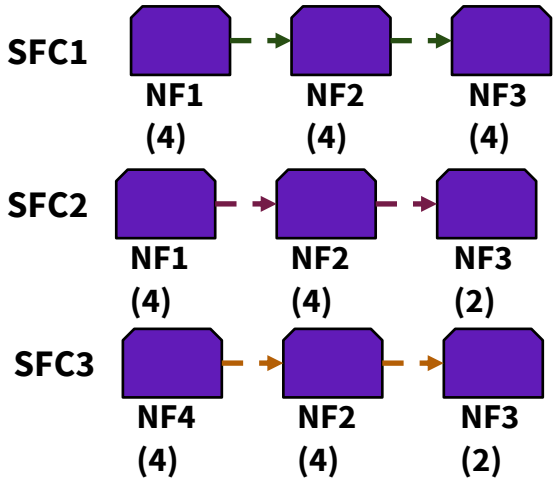
VNF Placement

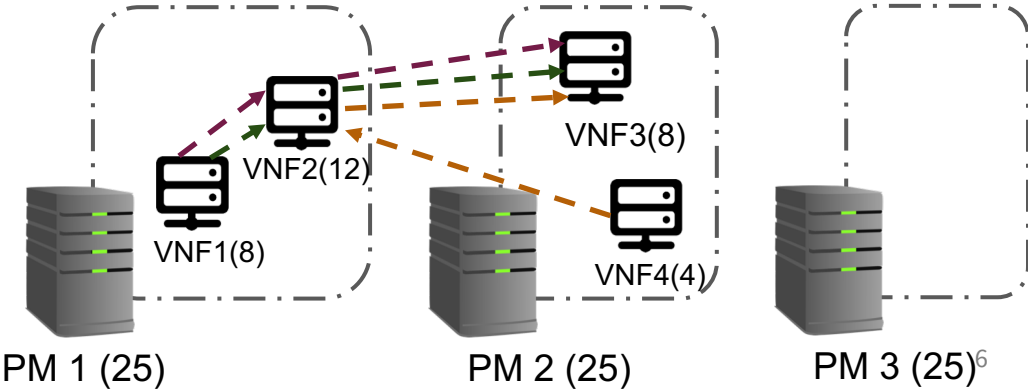
- Service Function Chain (SFC) is group of chained Network Functions (NF).
- NFs are processed in virtualized instances called VNFs.
- Goal is to place VNFs in physical network.
- The NFs must be processed in the same order as SFC



Static VNF Placement Approach

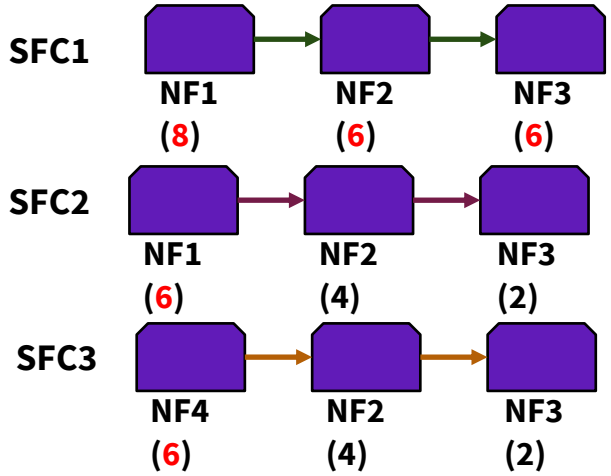
- Objective: Minimize energy cost
- Input: Resource demands of SFC
- Output: VNF Placement
- Constraint: Resource constraint
  - R_demand(VNFs) < R_capacity(PM)
- Approach: Fit as many VNFs in a PM so that less PMs are used

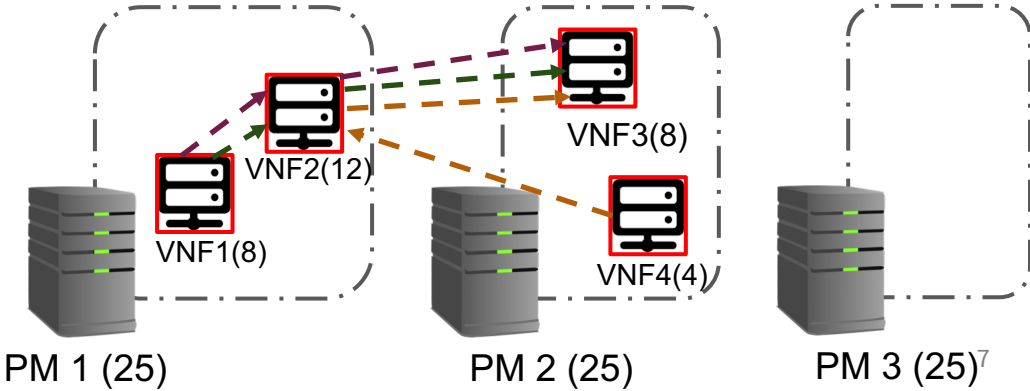




Time-Varied Workload Challenges

- Workload demands usually change over time.
- Resource violation can occur.
- How to process the increased demands?
- Energy cost can still be reduced
- **Solution: VNF Reconfiguration**





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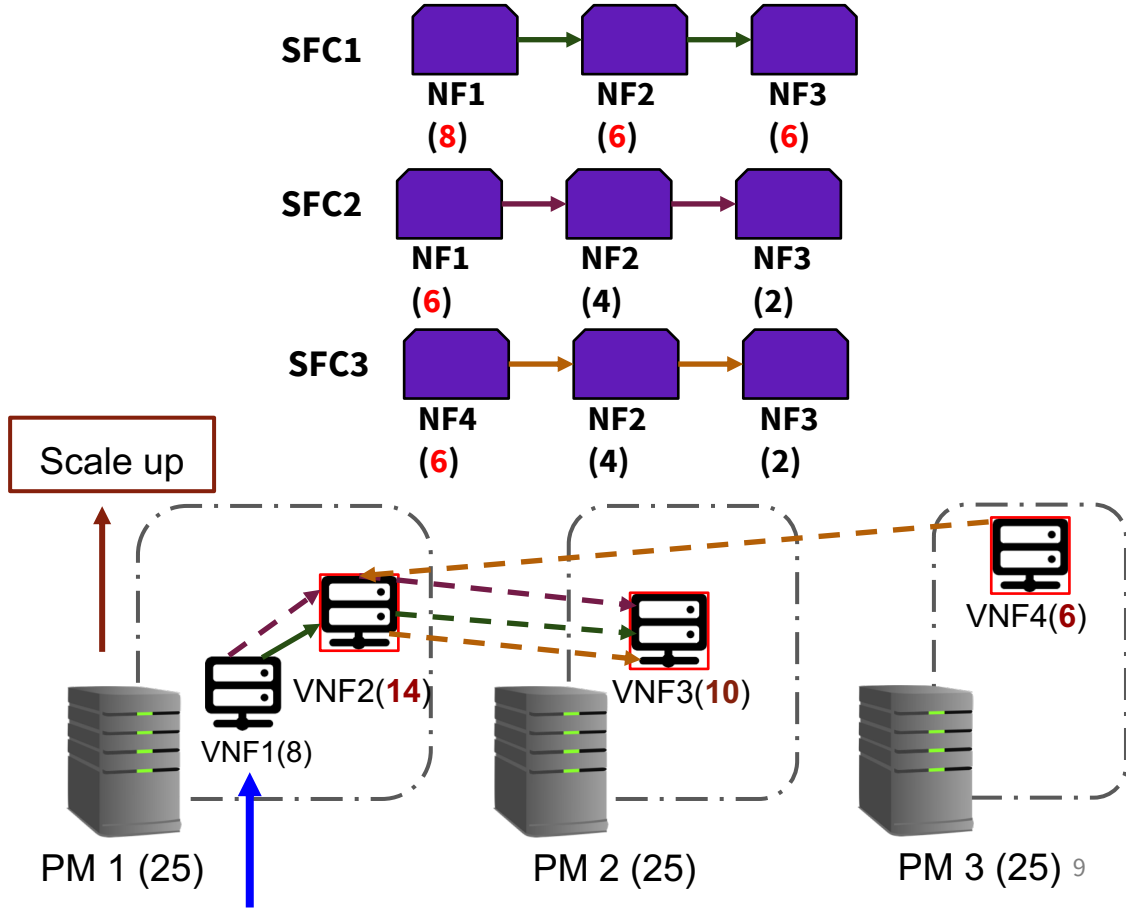
VNF Reconfiguration

Scale-up

- Increase the resources of a VNF
- Constraint: There should be enough residual capacity in PMs



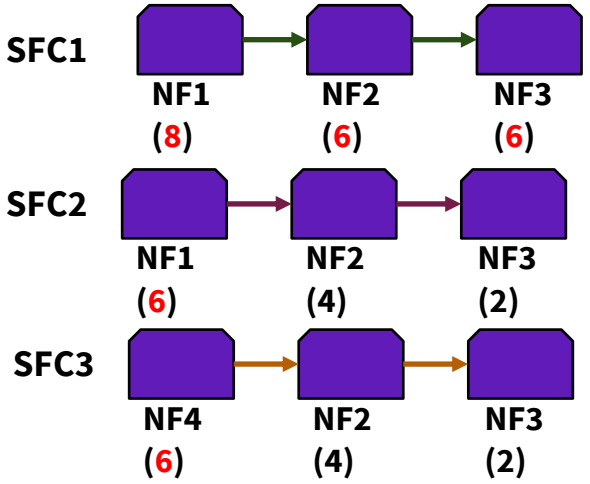
VNF Reconfiguration

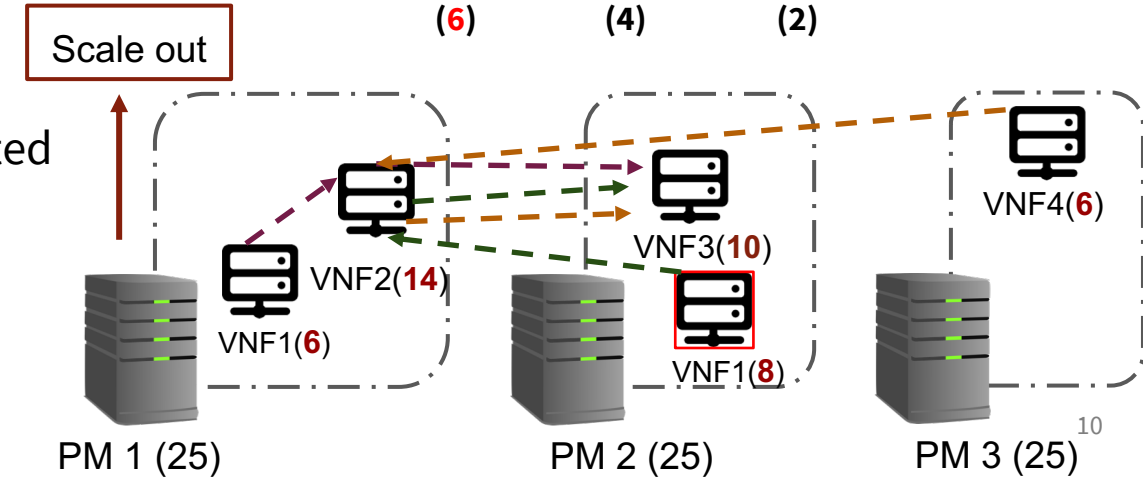
Scale-up

- Increase the resources of a VNF
- Constraint: There should be enough residual capacity in PMs

Scale-out

- Create a new instance of a VNF
- Constraint: Redirection of selected SFCs can cause delay





VNF Reconfiguration

Scale-up

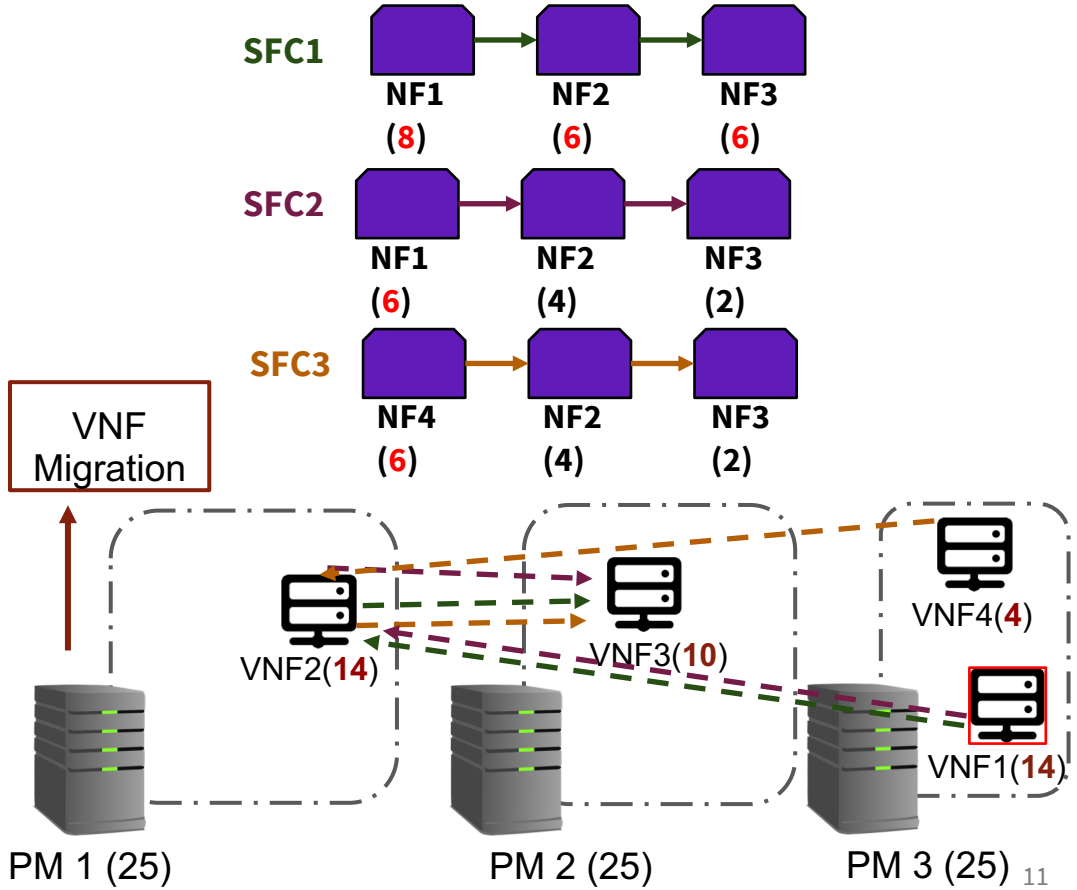
- Increase the resources of a VNF
- Constraint: There should be enough residual capacity in PMs

Scale-out

- Create a new instance of a VNF
- Constraint: Redirection of selected SFCs can cause delay

Migration

- Migrate VNF to another PM
- Constraint: Migrating all SFCs can cause delay, downtime etc.



Problem Definition: VNF Reconfiguration Problem

Each SFC *s* with a chain of NFs $\{n_1, n_2, \ldots n_f\}$

INPUT
SFCs
Resource demand
Bandwidth requirement

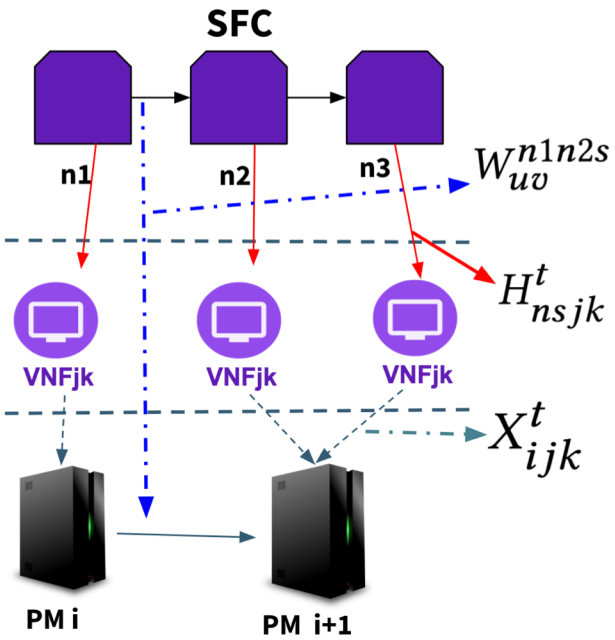
OUTPUT
NF <--> VNF Placement
VNF resource capacity

VNF V_{jk} , j is type of VNF and k is instance

INPUT
VNFs Resource Capacity
PM Resource capacity
PM status

OUTPUT
VNF <--> PM Placement
Reconfiguration Solution

PM P_i , i^{th} PM



Multi-tenant VNF
Type of NF = Type of VNF

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Objectives & Approach

- The objective is to address the tradeoff between reducing the energy cost and VNF reconfiguration.
  - Which reconfiguration solution should be chosen?
- Approach: Integer Linear Programming (ILP) formulation to get an optimal solution

ILP Formulation

ILP Formulation: Resource Constraints

R11	R21	R31
4	6	6

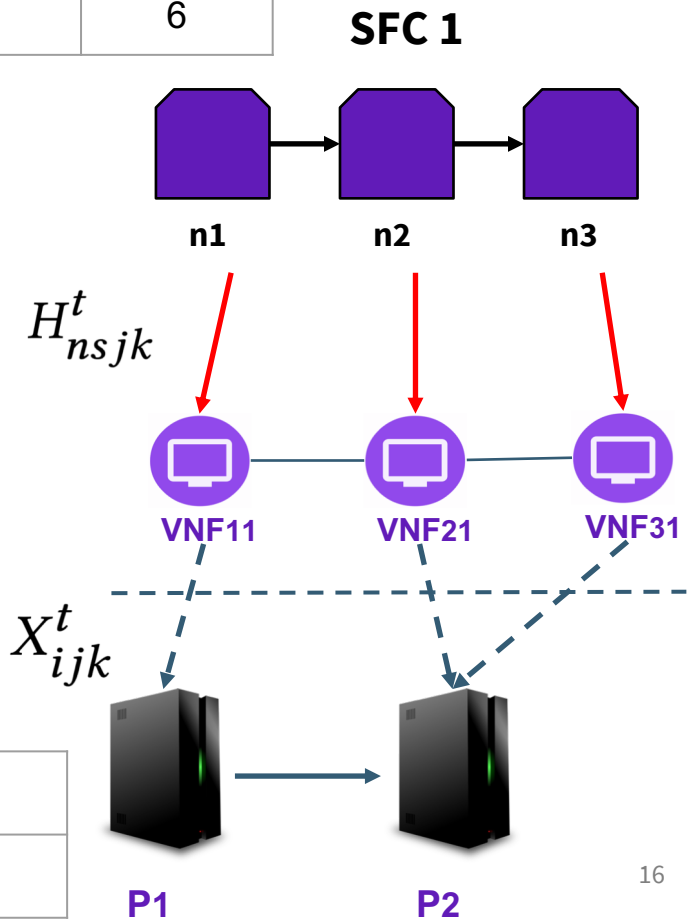
1. Constraint 1
* VNF Resource Constraint

$$\sum_{n=1}^{N}\sum_{s=1}^{S} H_{nsjk}^{t} * R_{ns} \leq C_{jk}^{t}, \forall j \in V, \forall k \in K$$

Type(n) == Type(j)

2. Constraint 2
* PM Resource capacity constraint
* VNF <--> PM

$$\sum_{k=1}^{K}\sum_{j=1}^{V} X_{ijk}^{t} * C_{jk}^{t} < M_i, \forall i \in P, t \in T$$



M1	M2
25	35

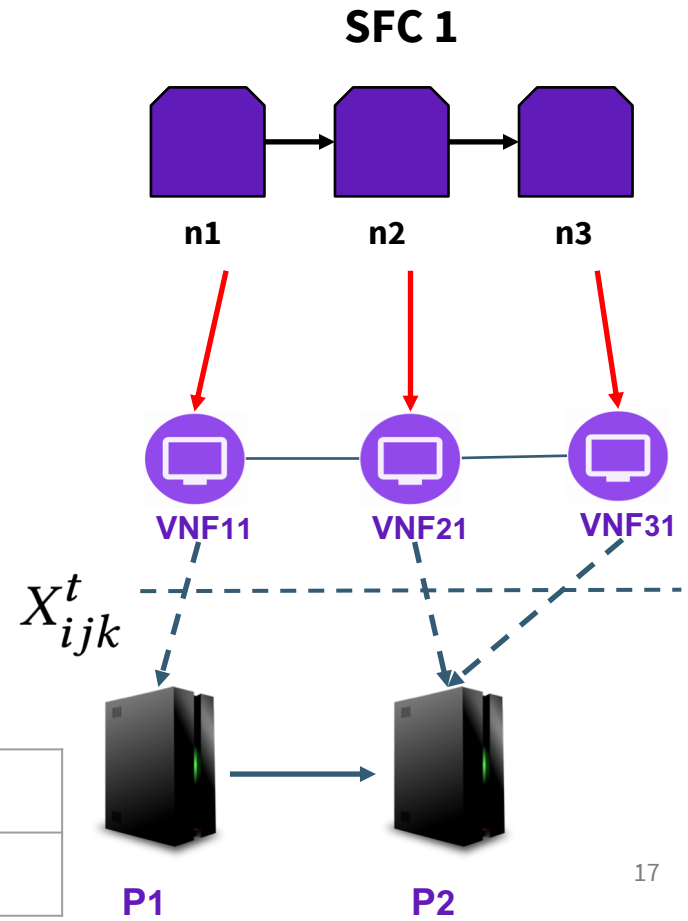
ILP Formulation: Placement Constraints

3. Constraint 3
* VNF Placement constraint
* VNF should be placed on active PM only

$$X_{ijk}^{t} < A_{i}^{t}, \forall i \in P, j \in V, k \in K, t \in T$$

4. Constraint 4
* Each VNF should be placed on one PM only

$$\sum_{i=1}^{P} X_{ijk}^{t} = 1, \forall j \in V, k \in K, t \in T$$



A^1_1	A^1_2
1	1

ILP Formulation: Link Constraints

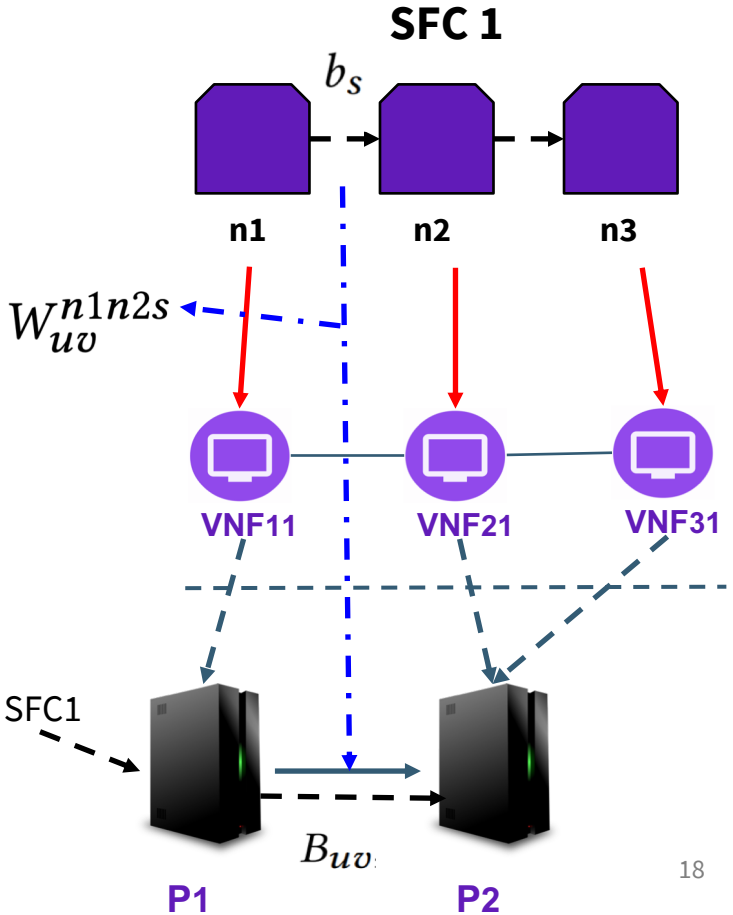
5. Constraint 5
* Link Capacity Constraint

$$\sum_{n1n2=1}^{L^s} \sum_{s=1}^{S} W_{uv}^{n1n2s} * b_s \leq B_{uv}, \forall uv \in L$$

6. Constraint 6
* Flow conservation constraint

$$\sum_{v=1}^{P} W_{uv}^{n1n2s} - \sum_{v=1}^{P} W_{vu}^{n1n2s} = HX_u^{n1s} - HX_u^{n2s}, \forall u \in P,$$

$$\forall n1, n2 \in N | n2 \in N^s(n1) n2 > n1, \forall s \in S$$



ILP Formulation: Objective Function

X^{t-1}_{211}	X^{t-1}_{221}	X^{t-1}_{231}
1	1	1

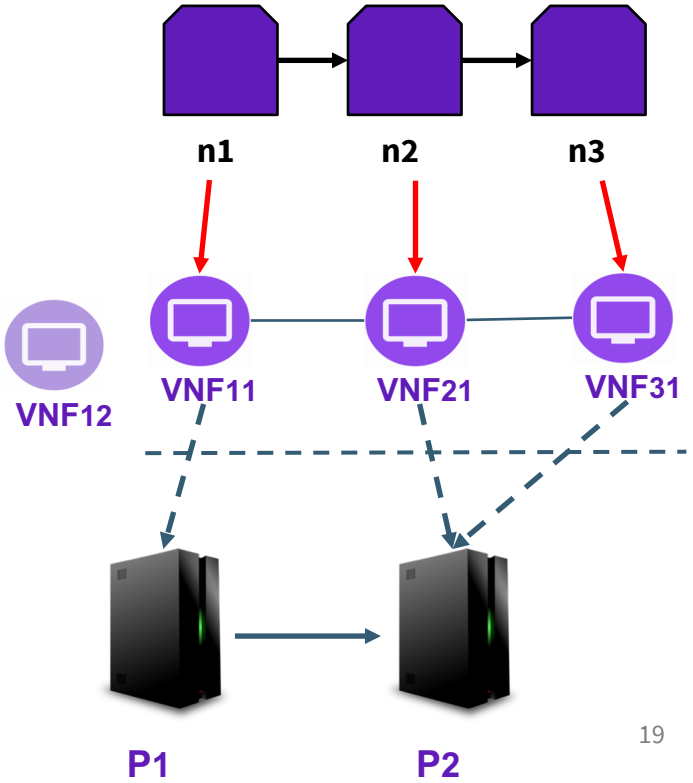
Minimize

Energy Cost + Migration Cost + Instantaniation Cost

Minimize

$$\alpha \sum_{i=1} A_i^t + \beta \sum_{i=1}^{P} \sum_{j=1}^{V} (X_{ijk}^{t-1} * [1 - X_{ijk}^t]) * Mig_{jk}$$

$$+\gamma \sum_{k=1}^{K} \sum_{j=1}^{V} (C_{jk}^t * [1 - C_{jk}^{t-1}]) * I_{jk}$$



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Experimental Setup

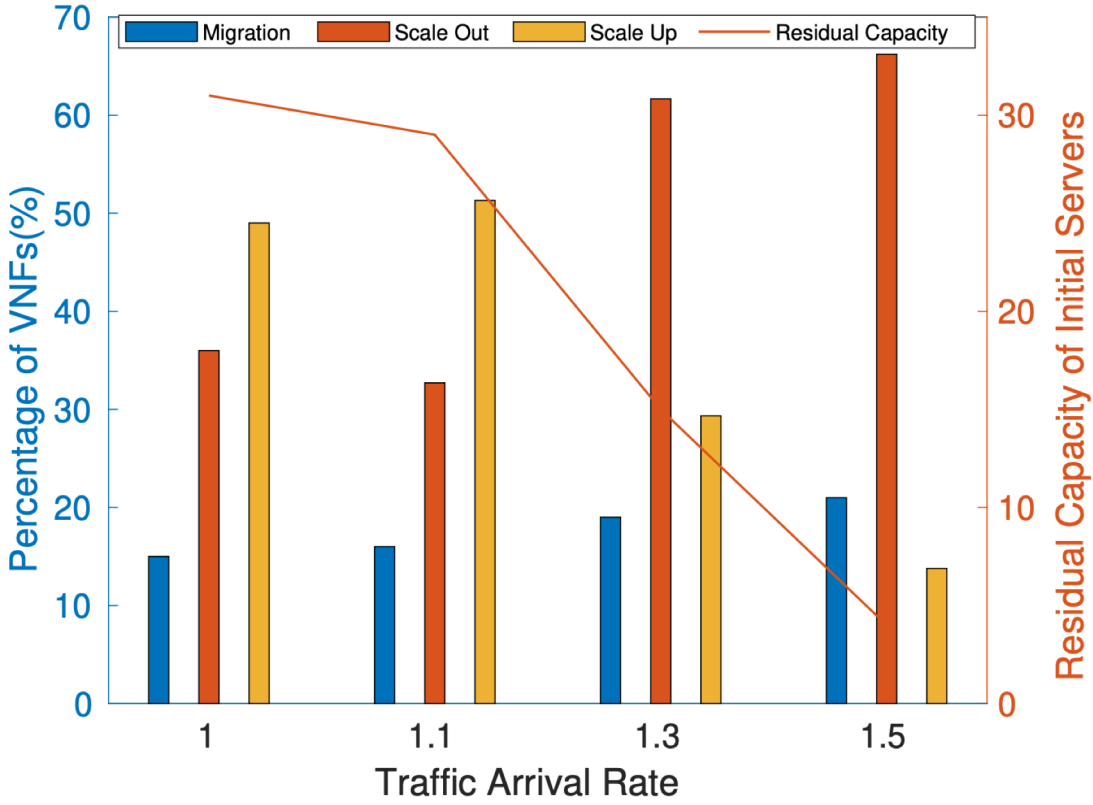
- Service Function Chains
  - Number of SFCs: 60
  - Number of NFs in one SFC: 5
  - Resource demands randomly generated
- Physical Infrastructure:
  - Number of PMs: 50
  - Heterogeneous resources
  - Bandwidth capacity of physical link: 1Gbps
- Solver: IBM CPLEX

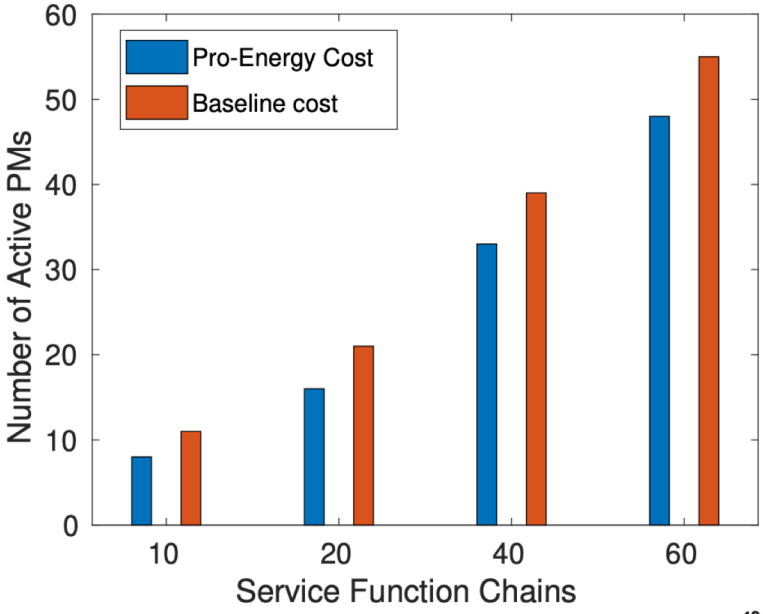
Network Service	VNF Chain	Bandwidth
Web service	NAT-FW-TM-WOC-IDS	100 kbps
VoIP	NAT-FW-TM-FW-NAT	64 kbps
Video Streaming	NAT-FW-TM-VOC-IDS	4 Mbps

Network services consisting of Network Address Translation (**NAT**), Firewall (**FW**), Traffic Monitor (**TM**), WAN Optimization Controller (**WOC**), Intrusion Detection System (**IDC**) and Video Optimization Controller (**VOC**)

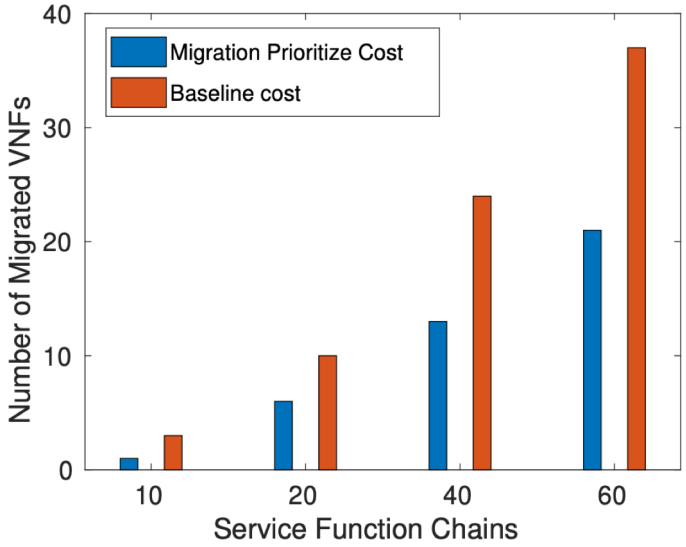
Results: Reconfiguration Solutions

- Reconfiguration solutions with different traffic arrival rate
- Initially scale up is the most preferred solution
- As traffic increases, residual capacity of PM decreases
- Scale out becomes more preferred than Migration as traffic rate increases

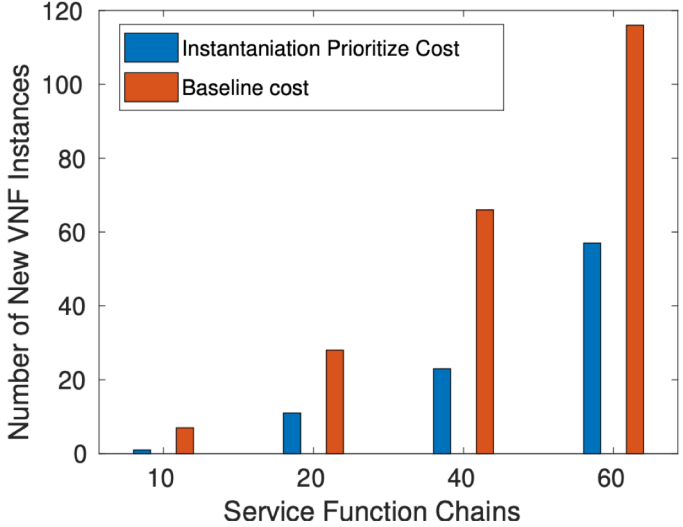




Prioritize Energy Cost



Prioritize Migration Cost

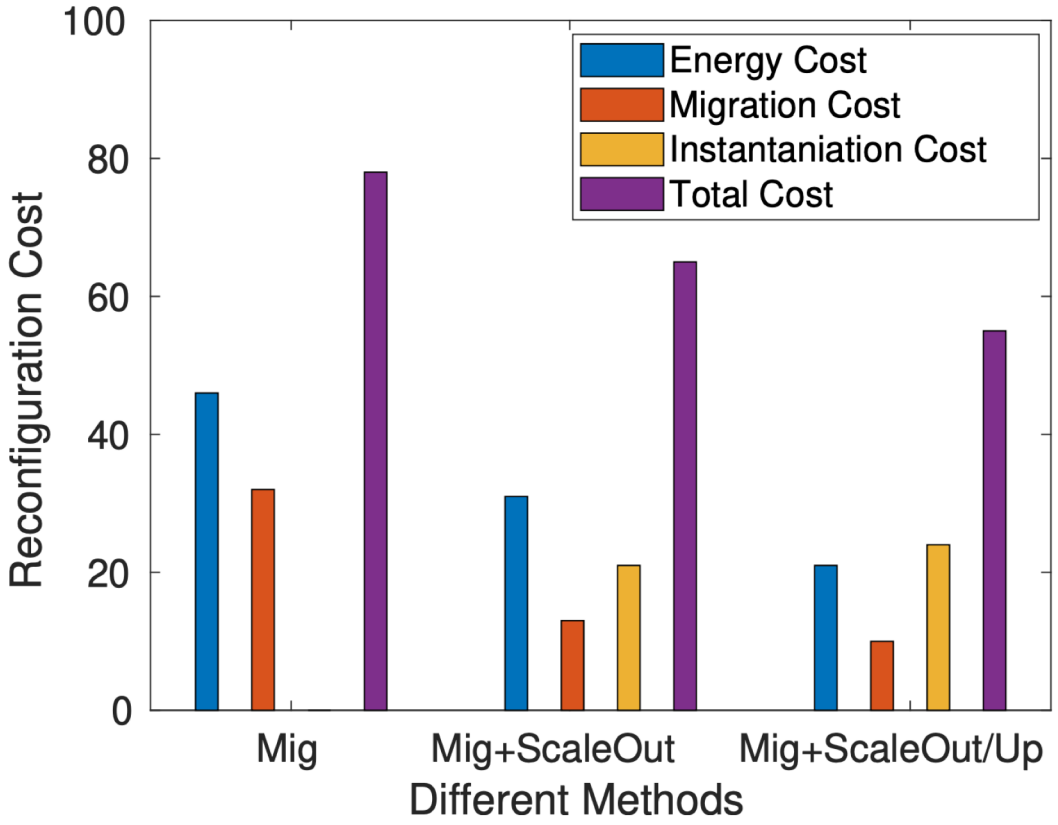


Prioritize Instantaniation Cost

Results: Tuning ILP Parameters

Results: Importance of Reconfiguration Costs

- Only Migration has the highest cost since it's oblivious
- Migration + Scale out helps in reducing cost further
- All three methods gives the least cost since ILP solver can use both scale out/up to reduce reconfiguration cost further.



Conclusions

- Reconfiguration solutions are highly beneficial for time-varied workload.
- There can be a tradeoff between reducing energy cost and VNF reconfiguration cost.
- We have proposed a ILP formulation for VNF reconfiguration problem.
- We have used a two level placement solution to solve this problem.
- Preferred reconfiguration solution:
  - Scale up is the most preferred
  - As traffic increases, scale out is preferred more
- As work in progress, we will propose a heuristic solution for this problem.

THANK YOU

Please don’t hesitate to reach us if you have any **questions**