Deploying Multiple Service Chain (SC) Instances per Service Chain

BY
ABHISHEK GUPTA
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Virtual Network Function (VNF) Service Chain (SC)

Service Chain 1

- VNF 1: Session Border Controller
- VNF 2: Quality of Service

Service Chain 2

- VNF 1: NAT
- VNF 2: Application Optimizer
- VNF 3: WAN Acceleration
Multiple VNF SC Placement and Routing
1 SC instance for each SC
Single Instance Per SC

3 Demand Requests
\[ r_1 = 14 \rightarrow 1, SC1 \]
\[ r_2 = 4 \rightarrow 7, SC1 \]
\[ r_3 = 14 \rightarrow 1, SC2 \]
\[ r_4 = 7 \rightarrow 4, SC2 \]
Multiple Instances per SC

Service Chain 1
Service Chain 2

3 Demand Requests

\[ r_1 = 14 \rightarrow 1, SC1 \]
\[ r_2 = 4 \rightarrow 7, SC1 \]
\[ r_3 = 14 \rightarrow 1, SC2 \]
\[ r_4 = 7 \rightarrow 4, SC2 \]
Inferences and Questions

- 1 SC instance per SC leads to suboptimal results

- Having SC instances replicated on every node will lead to optimal results
  - Large capital expenditure to make all nodes NFV capable
  - High Orchestration Overhead for large number of instances

- The question therefore becomes:
  - How many SC instances to deploy to reduce bandwidth consumption while also reducing nodes used?

- We develop a heuristic to help us chose the right number of instances (SPTG)
Issue of symmetric flows

VNFs placed in different nodes
Continued…

VNFs placed in same node
Continued…

- Placing VNFs for SC at different nodes
  - makes symmetric flow take longer path

- Placing VNFs for SC at one node
  - symmetric flow takes shorter path
  - placement and routing becomes trivial
  - chaining aspect is forgone
  - Is this more realistic?
  - Represents the case of a DC
Configuration 1 – (ILP, CG)
CG Model

RMP: Selects the best configurations, one for each chain

Dual Values

Yes

PP: Generation of a potential set of paths for chain #1

No

Optimality Condition Satisfied

Negative Reduced Cost

Yes

PP: Generation of a potential set of paths for chain #2

...

...

PP: Generation of a potential set of paths for chain #i

...

LP is solved optimally

Solve exactly ILP associated with the last RMP

ε- optimal ILP solution
Configuration 2 – (2 Phase Model)

Traffic flows are clustered and then model chooses appropriate configuration.
Comparison (ILP, CG, 2 Phase Model)

![Network Topology Diagram]

![Bandwidth Chart]

- Network Topology:
  - 4 node
  - 5 node
  - 6 node

- Bandwidth (Gbps):
  - ILP
  - CG
  - 2PhMod
  - ASP

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Full Traffic Matrix, 1 SC deployment, 1 SC instance

All nodes are NFV-capable.
All node pairs have requests for the same service chain.
Grouping of traffic pairs
Continued …

• Create traffic flow groups

• Assign dummy SC Id’s to traffic flow groups

• Big Question: How to do we make traffic groups?

• Model accounting for traffic groups becomes quadratic. Subsequent, linearization reduced the scalability of the model

• We, therefore, use a heuristic to do make the traffic groups
Grouping traffic flows around a node

• Betweenness Centrality
Group around node pairs of the graph

- A and B can also be source and destination
- Done for each SC
Continued…

• Ordered node pair with highest traffic flow count passing through on shortest paths

![Graph showing node pair and traffic flows]

• Traffic flows which share sub-paths in common

• Deploying one SC instance for each such group
Shortest Path Traffic Grouping (SPTG)

- **Given:** the number of instances for a SC, all node pairs in a graph G

- **The heuristic will:**
  1. Find the node pair with the largest number of (s, d) pairs
  2. This becomes another (s, d) pair group
  3. All the (s, d) pairs in the group are removed from the global (s, d) pair list
  4. Repeat step 1 to 3 until number of instances is reached
  5. Iterate through the remaining (s, d) pairs:
     1. Find best group based on which path length through node pair
     2. Add (s,d) pair to that group
2 phase model

- 1\textsuperscript{st} phase
  - Apply SPTG for each SC and create the required number of groups
  - Assign dummy SC ids to groups of (s,d) pairs

- 2\textsuperscript{nd} phase
  - Use the column generation model which decides on 1 SC instance per SC
  - \textit{Also we can control the number of nodes that can host VNFs, we refer to this number as ‘K’}
Assumptions

- All nodes are capable of hosting VNFs
- No CPU constraints are enforced
- No link capacity constraints are enforced
- Only one SC instance per SC model
- All traffic pairs have 1Gb traffic flow
NSFNET K=14

![Graph showing BW Used (Mbps) and Number of Nodes Used against the number of instances.](image-url)
NSFNET $K=14,5,4,3,2,1$
VNF Replica Constraints

![Bar chart showing VNF Replica Constraints](image-url)
Maximum Loaded Link Values for various $K$
Scalability of 2 Phase Model

![Bar Chart]

<table>
<thead>
<tr>
<th>Network Topology</th>
<th>CPLEX Time (ms in log-base-10 scale)</th>
</tr>
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<tbody>
<tr>
<td>COST239</td>
<td>5</td>
</tr>
<tr>
<td>NSFNET</td>
<td>6</td>
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<tr>
<td>US24</td>
<td>7</td>
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<tr>
<td>GERMANY50</td>
<td>9</td>
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</table>
Cluster Counts (Variable Traffic Flows – Uniform)
Continued…
Cluster Counts (Variable Traffic Flows – Skewed)
Future Work Directions

- **Cases where distribution of VNFs occur:**
  - Cases where CPU resources are constrained or VNF replicas (because of licenses) are enforced
  - Any additional cases?

- **Current results for only 1 service chain**
  - How to make sense of results in a multi-service chain scenario?
  - Same results repeated for 4 service chains?
  - Not all service chains use complete traffic matrix
  - 2 Phase Model tries to optimize placement and routing of each service chain
  - However, VNF replica enforcement will result in non-optimal placement and routing