Multi-domain non-cooperative VNF-FG embedding: DRL approach

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Outline

- Motivations
- Deep learning approach
- Multi Domain VNF-FG embedding problem
- DRL-based solution
- Decision maker
- Results
- Conclusions
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5G: One Network, many Industries

Builds on SDN/NFV to deliver service specific slices
- Mobile broadband
- Multimedia delivery
- Machine Type

Each slice has its requirements
- Industrial: low latency, limited bandwidth, many devices
- Health: low latency, high resiliency

Physical resources could belong to different operators!!!
The four NFV Pillars

Virtualized network functions
Reuse hardware across tenants
Chain virtual functions
Dynamic scaling of network services
VNF Placement

Firewall → Load balancing → Intrusion Detection System

High Volume Servers → Standard High Volume Switches → High Volume Servers
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Deep Learning Approach

– Machine Learning or Optimization-based?
  • Optimization-based approaches need accurate models
  • Difficulties in determining accurate models for complex networks (multi-hop)(*)
  • Machine learning addresses this by learning hidden characteristics of any network

– Why go deep?

– Why reinforcement learning?

Deep Learning Approach

- Machine Learning or Optimization-based?
- **Why go deep?**
  - Data dependency

- Why reinforcement learning?

[https://www.sumologic.com/blog/machine-learning-deep-learning/](https://www.sumologic.com/blog/machine-learning-deep-learning/)
Deep Learning Approach

– Machine Learning or Optimization-based?
– Why go deep?
– **Why reinforcement learning?**
  • Its good performance and capability have been confirmed (*)

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Multi-Domain (MD) VNF-FG

- States (observations) = VNF-FG requests
- Action of each domain = Price per unit of resources
- Reward of each domain = Price x Amount of sold resources
MD VNF-FG

Reward is up to the Final Decision of the client (owner of the VNF-FG)
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DRL-based solution

• Based on Deep Deterministic Policy Gradient (DDPG)
• DDPG comprises Actor network and Critic network
• Actor network: Determine the policy
• Critic network: Evaluate the quality of the policy and improve performance of the actor

\[ a_t = \mu(s_t | \theta) + N \]

\[ e(s_t, a_t, r_t, s_{t+1}) \]
DRL-based solution

- Performance can be improved by adopting Convolutional Layer (*)
  → DNN = Convolutional Layers + FC layers

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Decision maker

- Deployed in client side
- Based on the price proposed by domains

Cost-based First Fit algorithm (CFF)
For VNF embedding:
Step 1: Sort substrate nodes in terms of cost
Step 2: Send a request to the domain of the lowest price node
Step 3: If the domain approves, deploy VNF. Otherwise, remove that node from the selection process and back to step 1
Until all VNFs deployed

For VL embedding:
Use Dijkstra algorithm to identify the lowest cost path to connect VNFs
→ Final allocation decision
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Results

Single domain vs Multiple domain

- **Reward**: The reward increases over time for both single and multiple domains, with CFF-SD and CFF-3D showing similar trends.
- **Normalized Price**: The normalized price also increases over time, with CFF-SD and CFF-3D showing similar performance.
- **% Deployed VNFS**: The percentage of deployed VNFS decreases over time, with CFF-SD showing a slight advantage over CFF-3D.
Results

• Load Balancing

<table>
<thead>
<tr>
<th>Domain</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>7.93</td>
<td>8.14</td>
<td>8.35</td>
</tr>
<tr>
<td>RAM</td>
<td>8.21</td>
<td>8.29</td>
<td>8.72</td>
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<tr>
<td>HDD</td>
<td>8.53</td>
<td>7.82</td>
<td>6.95</td>
</tr>
<tr>
<td>Capacity</td>
<td>540 Mbps</td>
<td>710 Mbps</td>
<td>570 Mbps</td>
</tr>
</tbody>
</table>
Results

• Comparison with Simulated Annealing
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Conclusions

• Confirmed abilities of DRL in solving complex networking problems, i.e. VNF-FG embedding
• Proposed a non-cooperative DRL framework for MD VNF-FG embedding
• Studied the behavior of local intelligence in non-cooperative manner → win-win situation: more deployed VNFs/VLs while the normalized prices do not skyrocket
Thank you