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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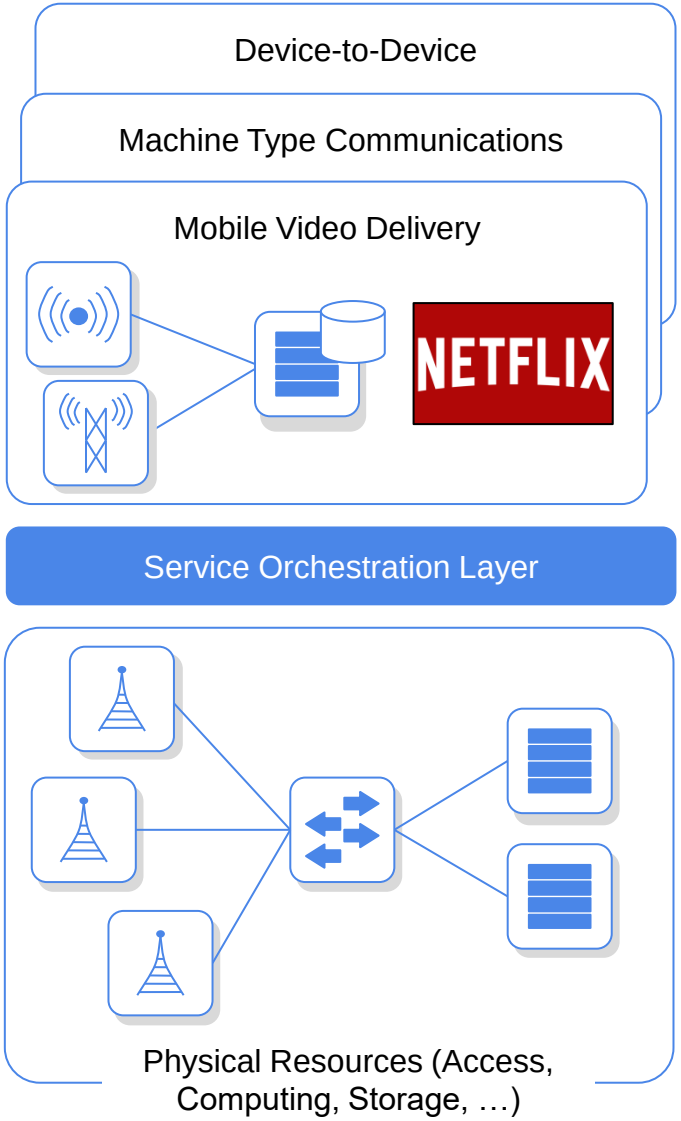
5G: One Network, many Industries

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!!!

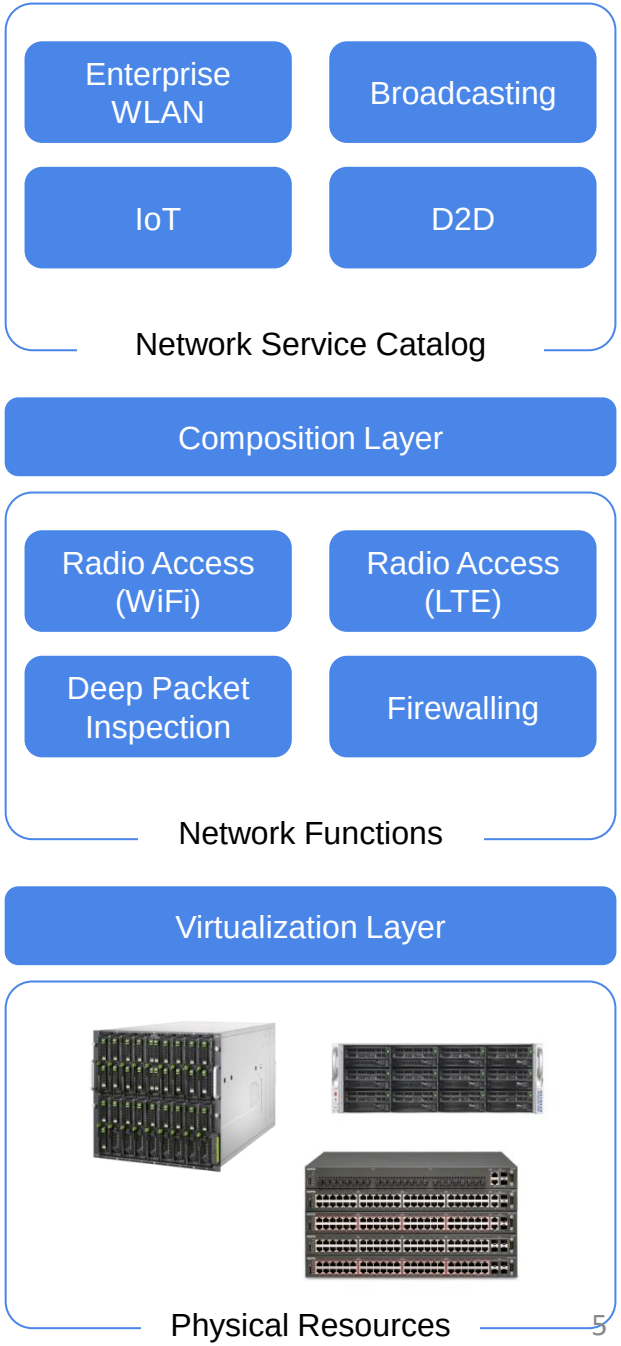
The four NFV Pillars

Virtualized network functions

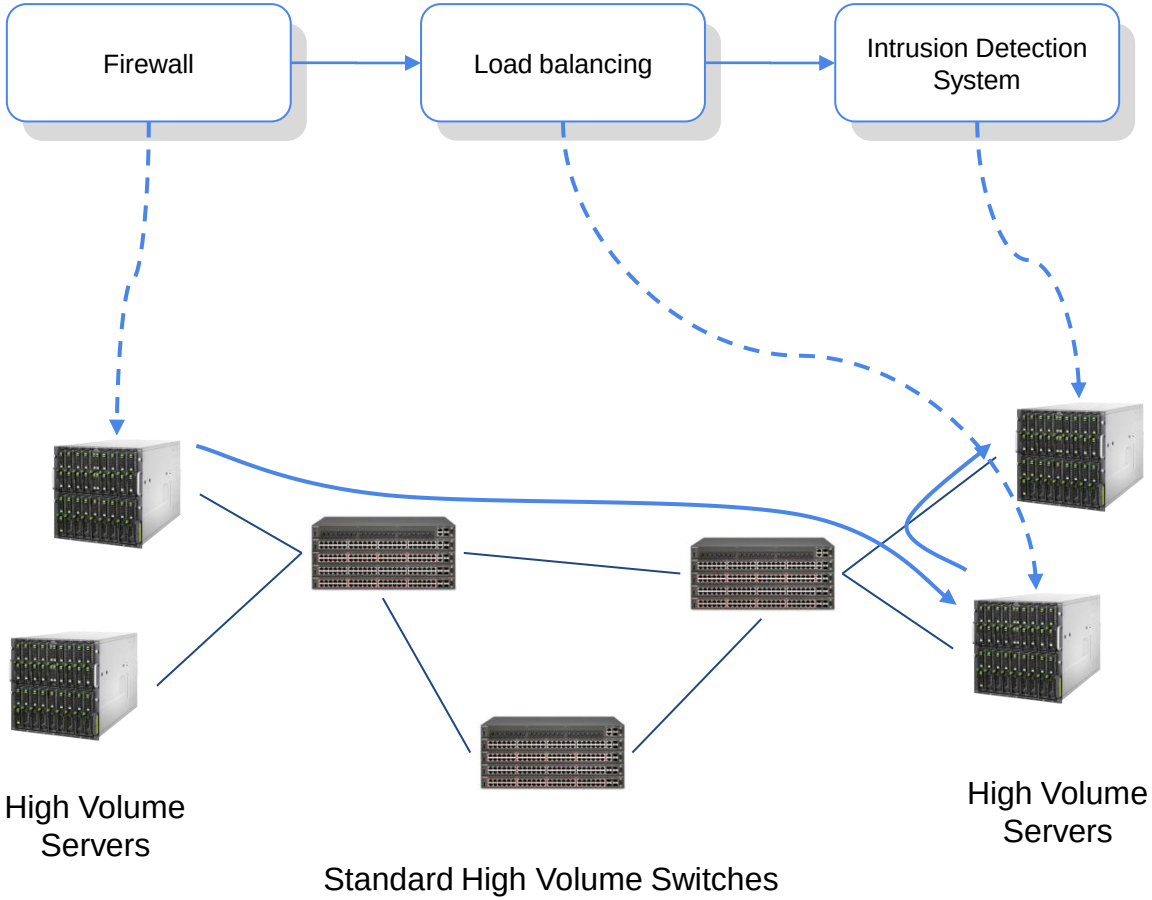
Reuse hardware across tenants

Chain virtual functions

Dynamic scaling of network services



VNF Placement



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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?

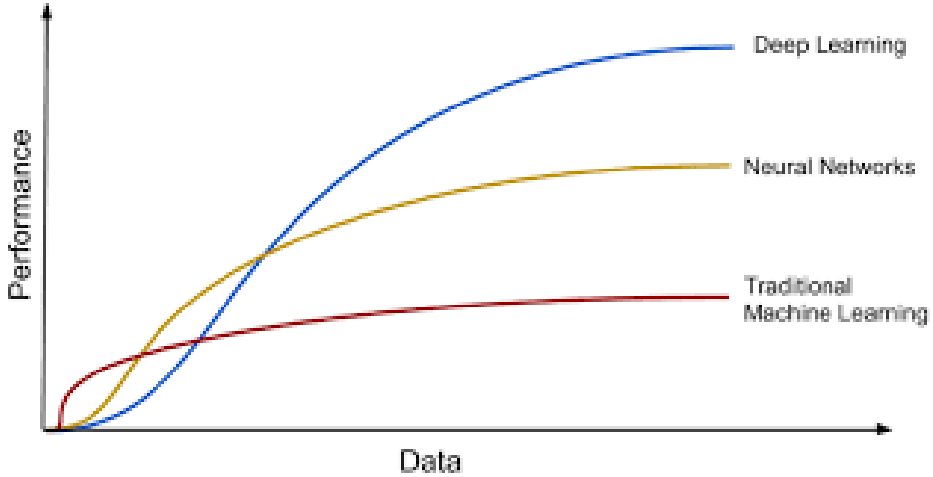
(*) Z. Xu *et al*., "Experience-driven Networking: A Deep Reinforcement Learning based Approach," *IEEE INFOCOM 2018 - IEEE Conference on Computer Communications*, Honolulu, HI, 2018, pp. 1871-1879.

Deep Learning Approach

– Machine Learning or Optimization-based?

– **Why go deep?**

Data dependency

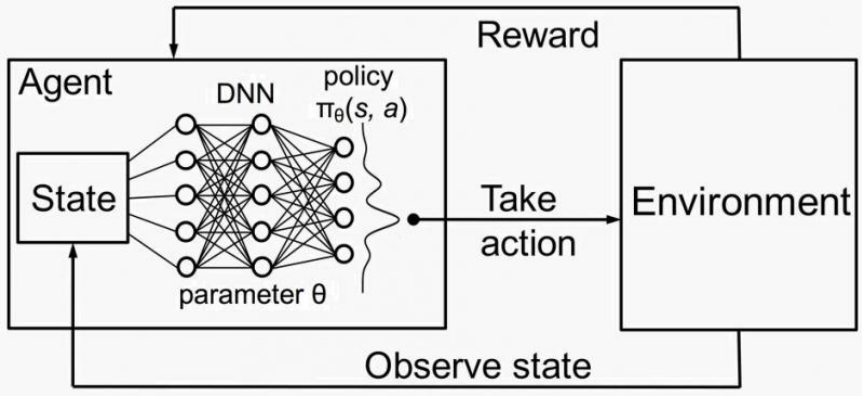


https://www.sumologic.com/blog/machine-learning-deep-learning/

– Why reinforcement learning?

Deep Learning Approach

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



(*): Asaf Valadarsky et al., "A Machine Learning Approach to Routing", CoRR, 2017

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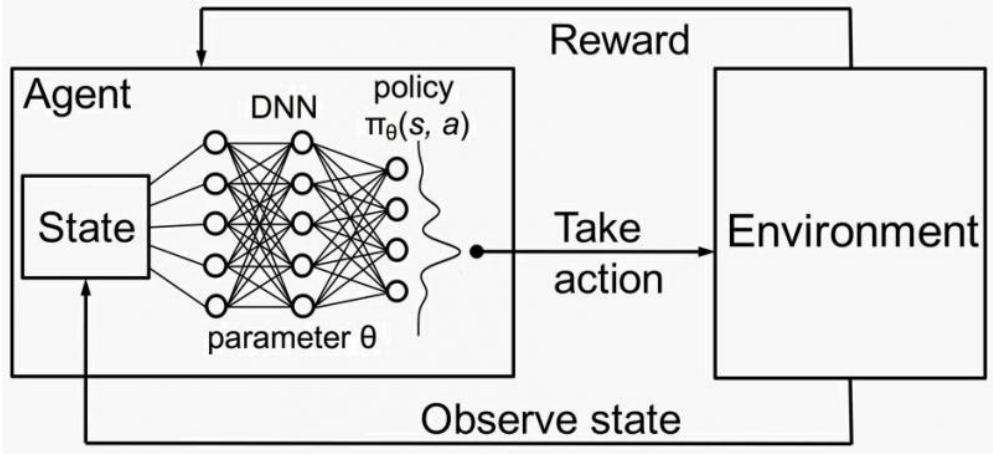
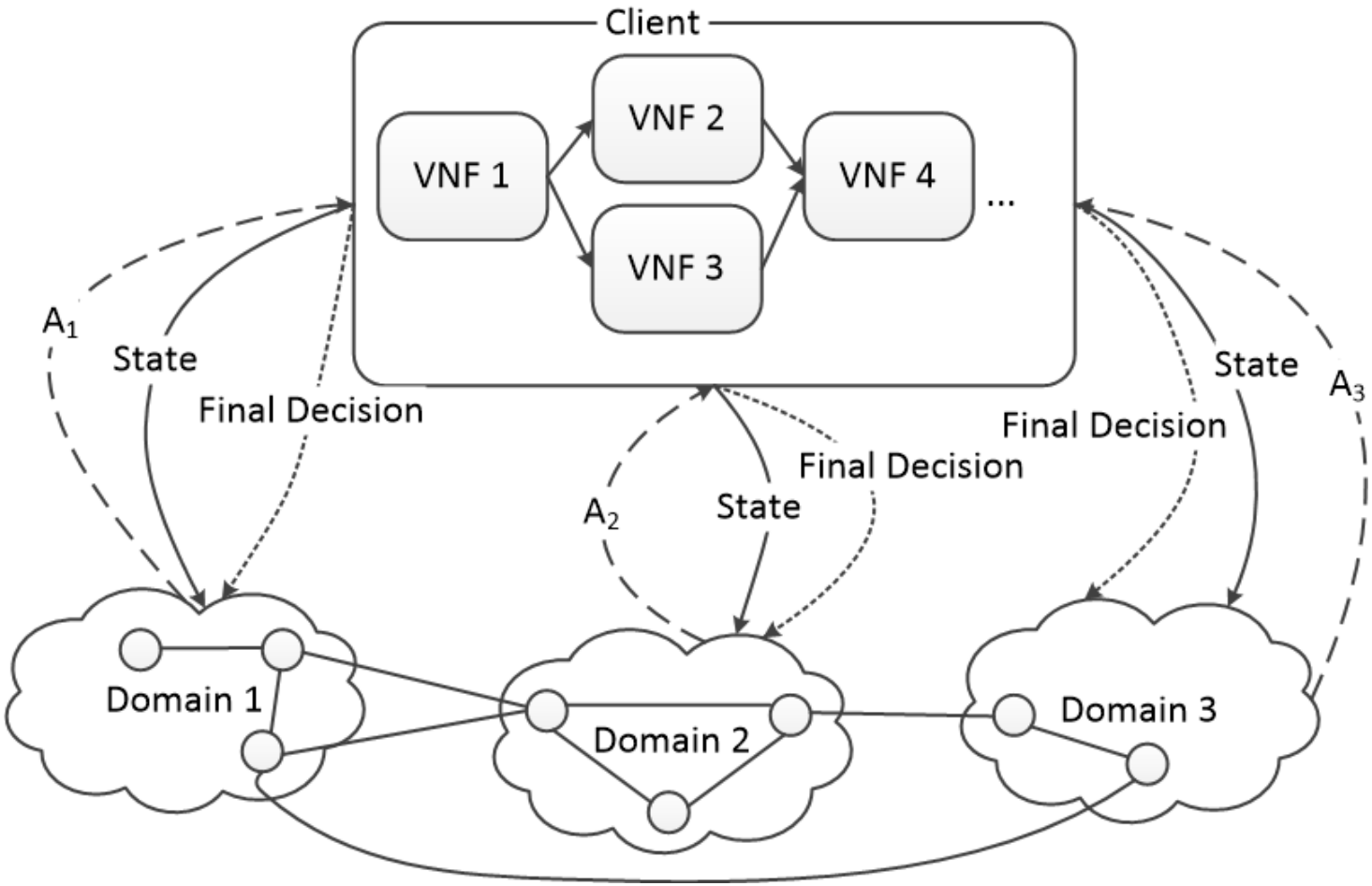
Multi-Domain (MD) VNF-FG

- 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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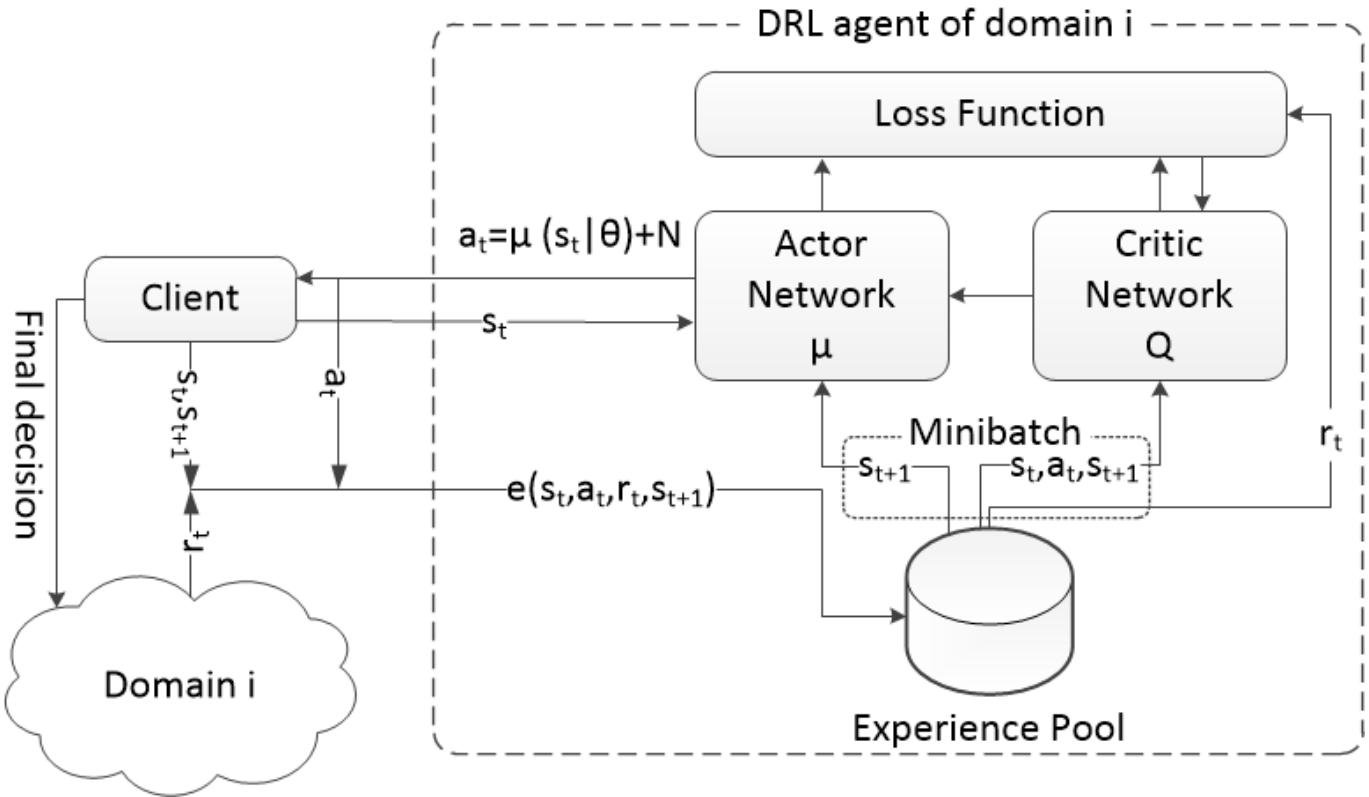
DRL-based solution

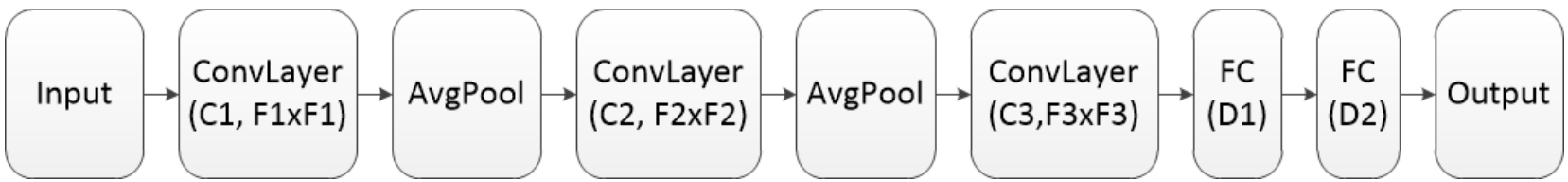
- Based on Deep Deterministic Policy Gradient (DDPG)
- DDPG comprises Actor network and Critic network
- Actor network: Determine the policy
- Critic network: Evaluate the quality of the policy and improve performance of the actor



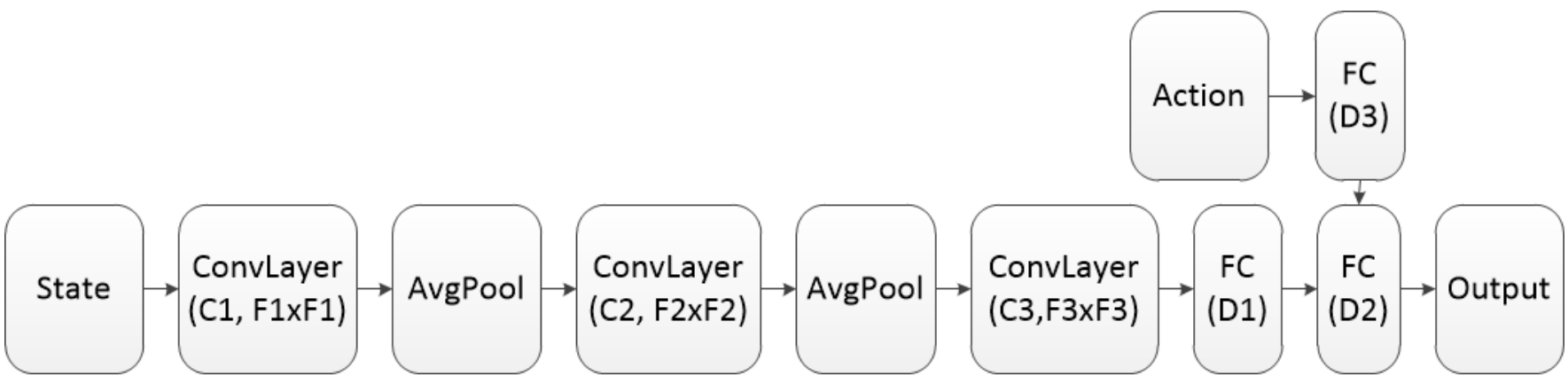
DRL-based solution

- Performance can be improved by adopting Convolutional Layer (*)

→ DNN = Convolutional Layers + FC layers



Actor Network



Critic Network

(*)Pham et al., "Deep Reinforcement Learning Based QoS-Aware Routing in Knowledge-Defined Networking," in Proc. EAI QShine, Dec. 2019, pp. 14–26

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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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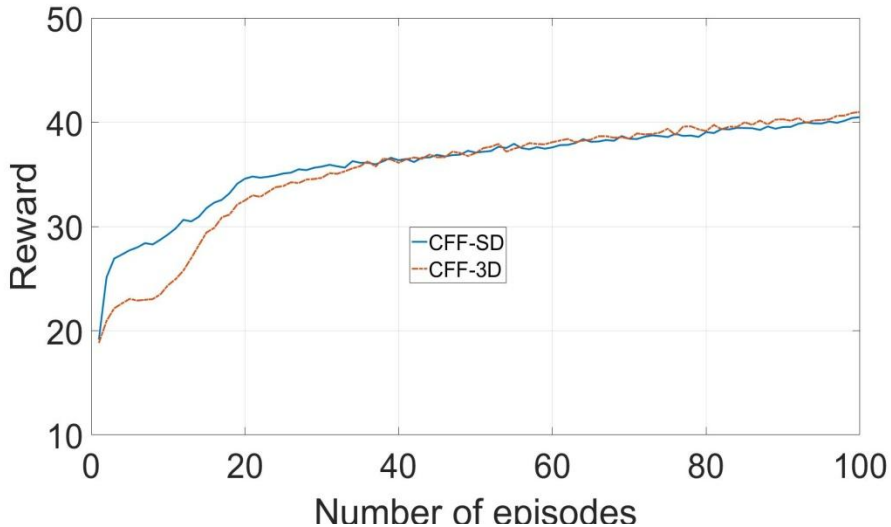
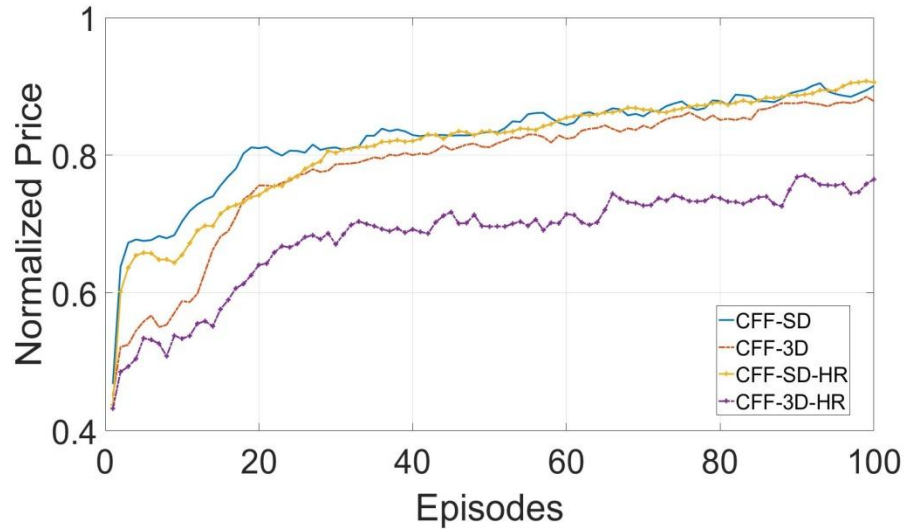
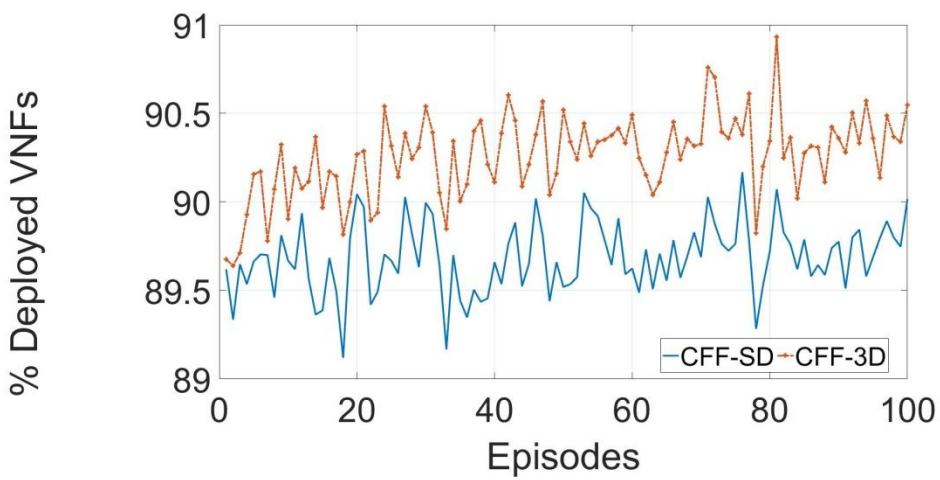
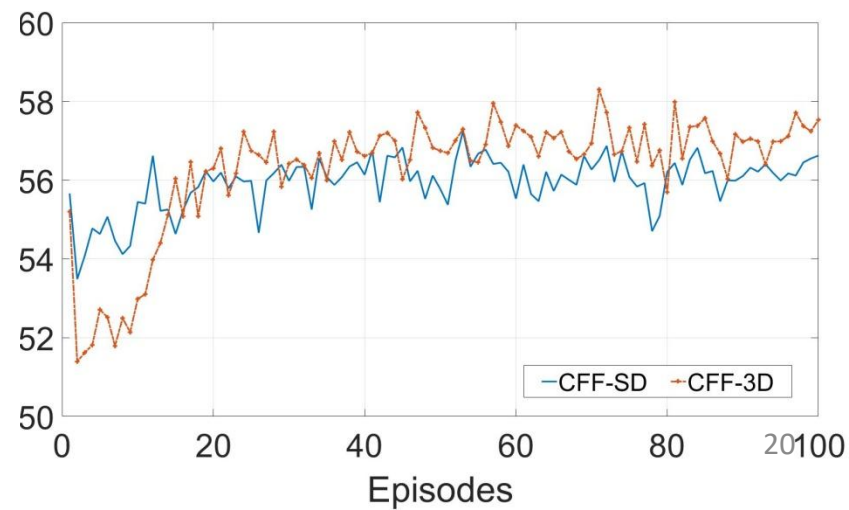
Results

Single domain vs Multiple domain





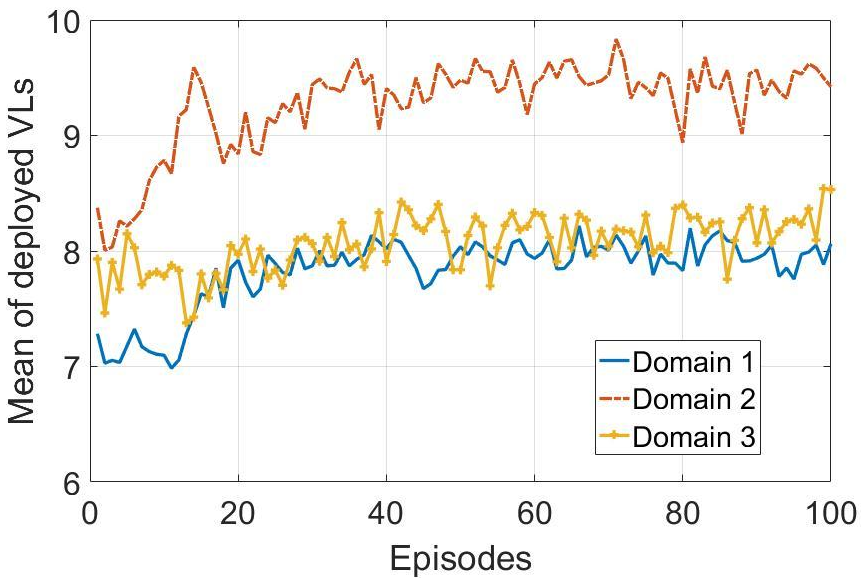


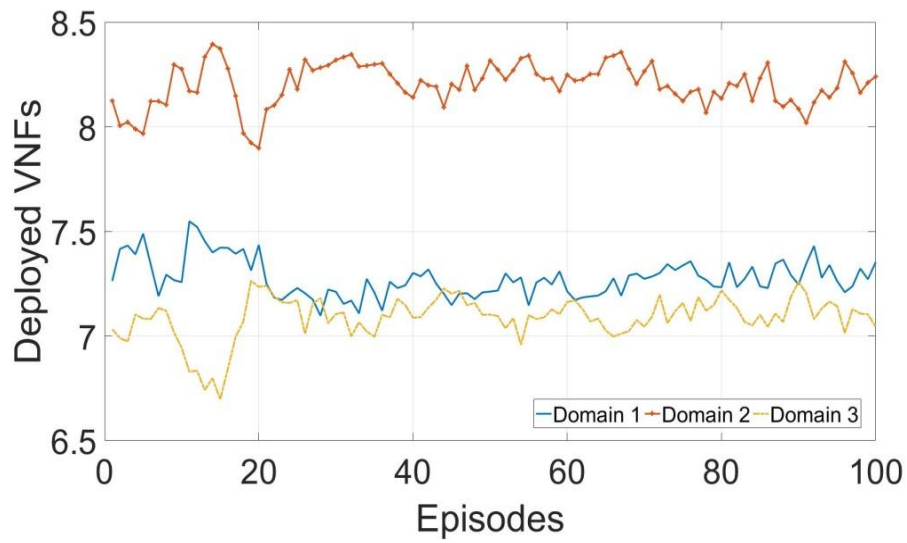


Results

- Load Balancing

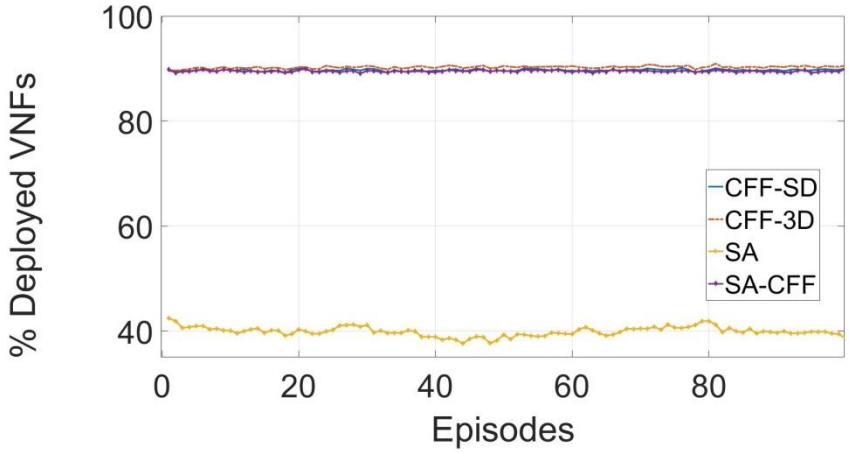
Domain	1	2	3
CPU	**7.93**	8.14	8.35
RAM	**8.21**	8.29	8.72
HDD	8.53	7.82	**6.95**
Capacity	**540 Mbps**	710 Mbps	570 Mbps

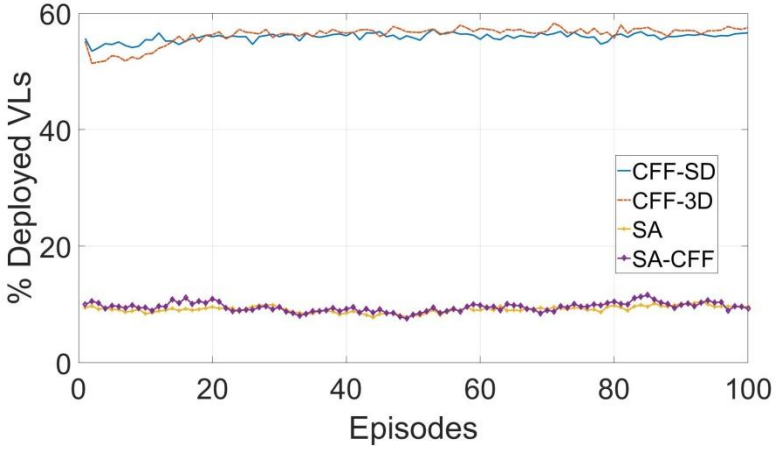




Results

- 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