Towards Chain-Aware Scaling Detection in NFV with Reinforcement Learning

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Network Function Virtualization

- **Introduce custom packet processing functions into the network**
  - offer the potential to enhance service delivery flexibility and reduce overall operational expenses
  - enable elastic scaling by creating and destroying VNF instances
- **Primary goals of elastic scaling**
  - satisfy service level agreements (SLAs)
  - minimize VNF operating cost

Firewall | **Caching Proxy** | **Intrusion Prevention** | **Traffic scrubber** | **Load balancer** | **SSL Gateway** | **WAN optimizer** | …

Existing Solutions

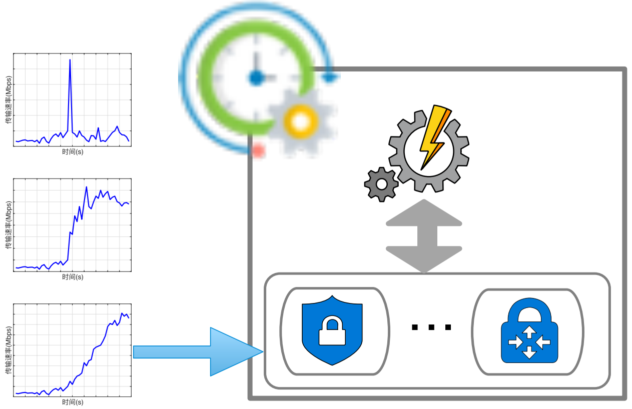
- **Rate-based**
  - Estimate the upcoming traffic rate and then compute the number of required instances that can process the estimated traffic demand.
  - Examples: Wang et al.[Cloud'16], SLFL[CloudNet'15], Zhang et al. [INFOCOM'17], VPCM [INFOCOM'18], Tang et al. [TPDS'19]
  - The dynamics of upcoming traffic in packet size and type affect instance number computation.
- **Status-based**
  - Achieve scaling detection based on VNFs' runtime status, including the application- and hardware-level parameters.
  - Examples: ENVI[ANCS'18]
  - Affected by the collected "raw" status information, which causes imprecise scaling decisions.

The Problem

Existing Solutions: Designed based on a simplified or inaccurate understanding of deployment environments.

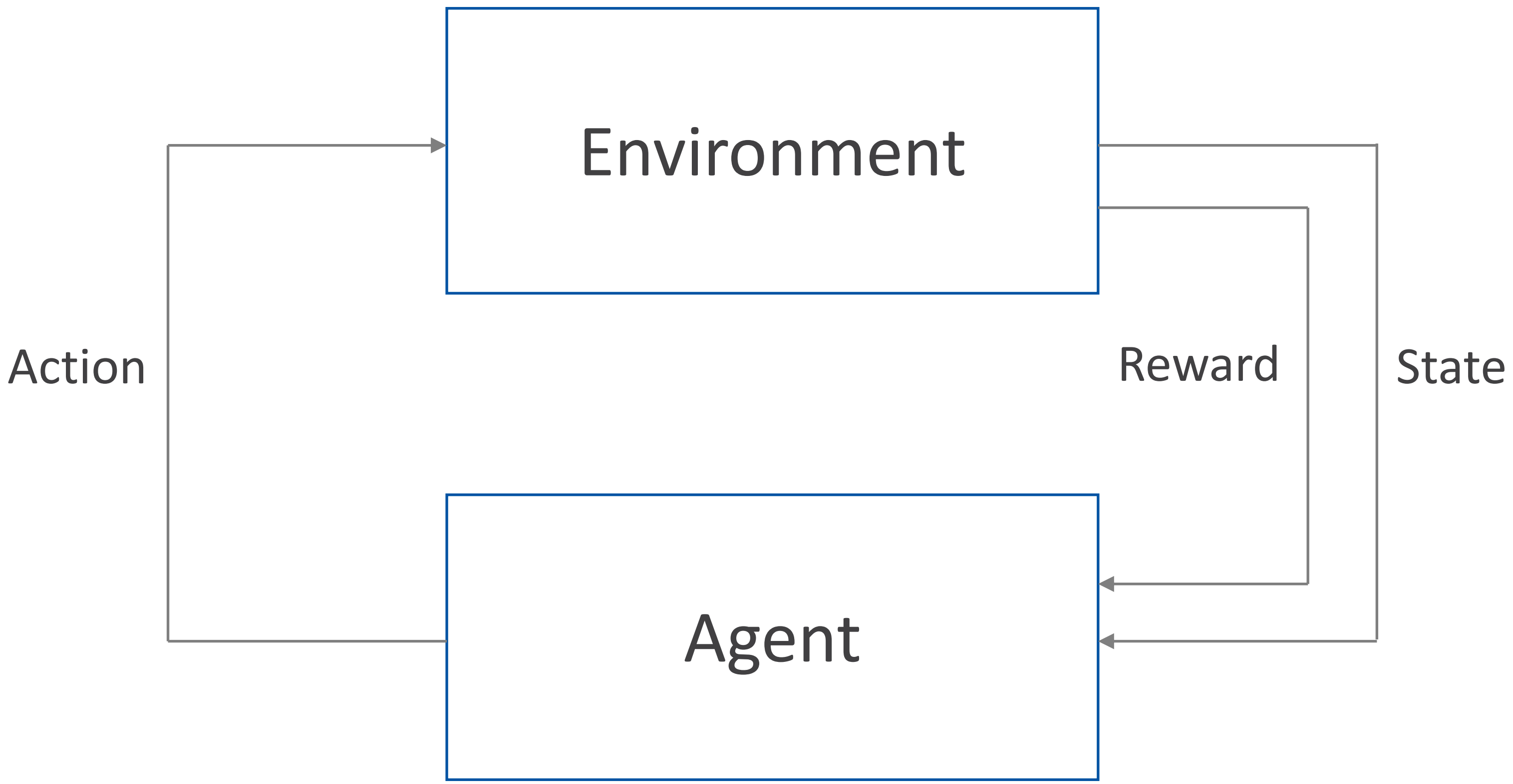
Problem: system environment affects the scaling mechanism

Environment and traffic load diversity → Policy change and parameter adjustment



Challenge： How to adjust the scaling strategy and parameters in real time with system changes?

Reinforcement Learning

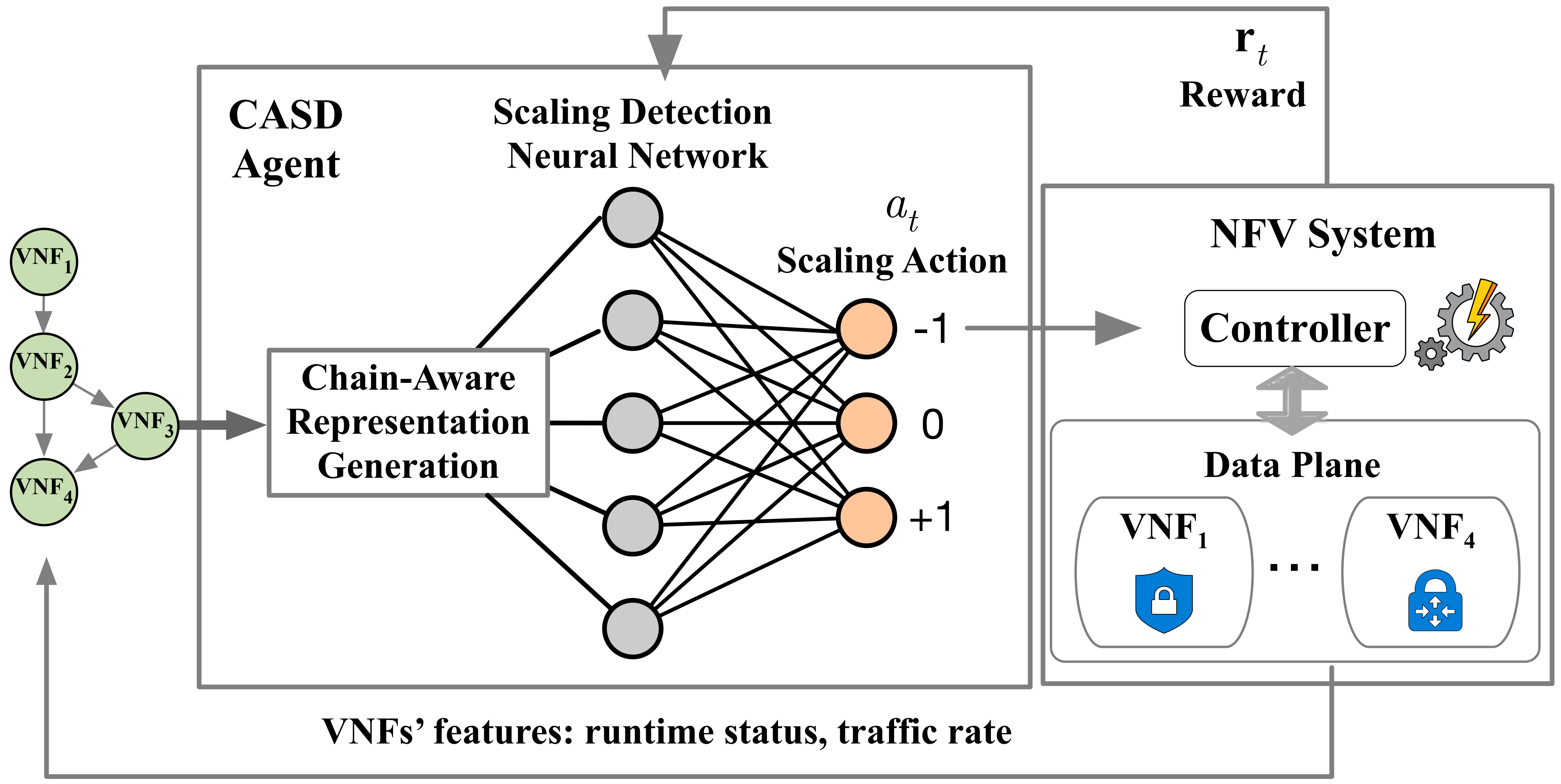


Solution: Chain-Aware Scaling Detection (CASD)

Talk Outline

- ~~Motivation~~
- **CASD Architecture**
- Evaluation Results
- Conclusion

CASD Architecture



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- CASD Architecture
  - Chain-aware Representation Generation
  - Scaling Detection Model
- Evaluation Results
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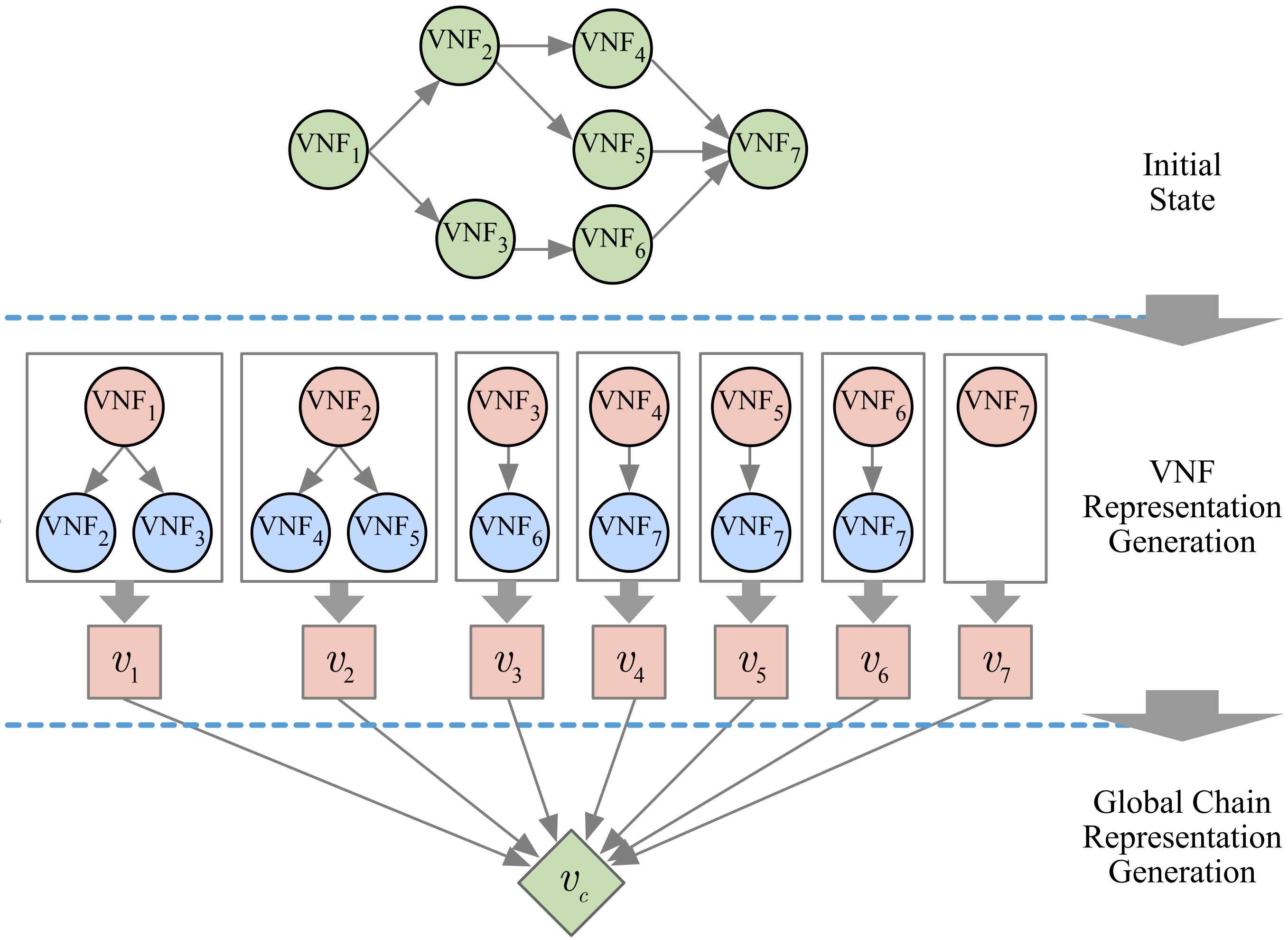
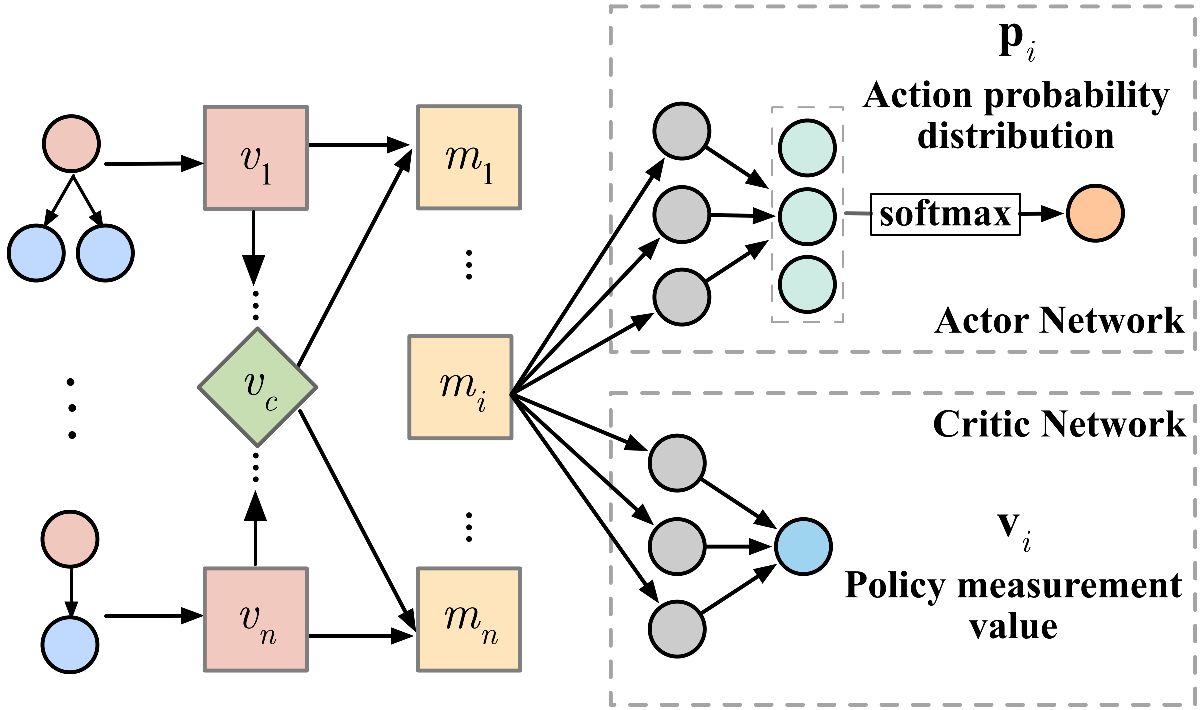
Chain-aware Representation Generation

- **VNF Representation**
  - Initial state: input, output, latency, cpu, memory
  - Not only capture its explicit state but also depict the effects of its children in the chain
- **Global Chain Representation**
  - regard the chain as a particular VNF summary node
- **Chain-aware Representation**
  - VNF Representation + Global Chain Representation



Scaling Detection Model

- **Neural Network Model**
  - Input: Chain-aware representation sequence
  - GRU: Capturing relationship of sequences
- **Training Method: A3C**
  - Actor Network: Obtain the probability distribution of scaling actions
  - Critic Network: Measure how well the policy performs



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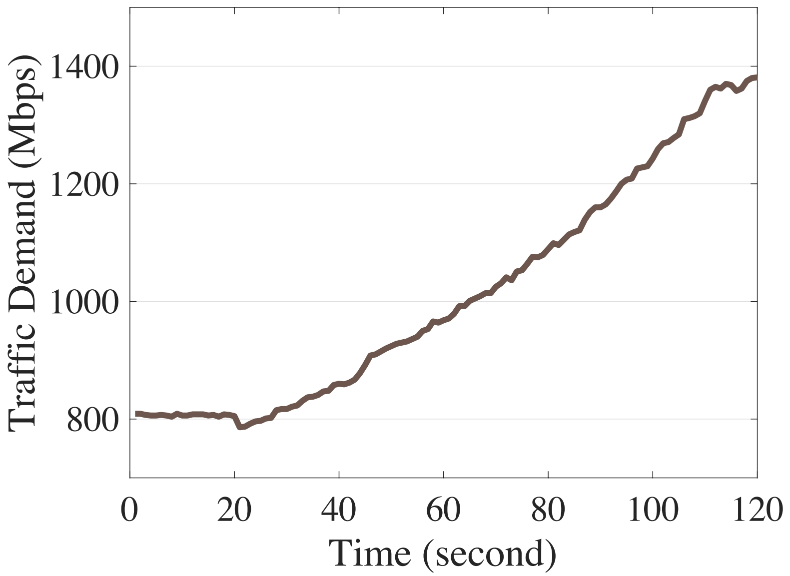
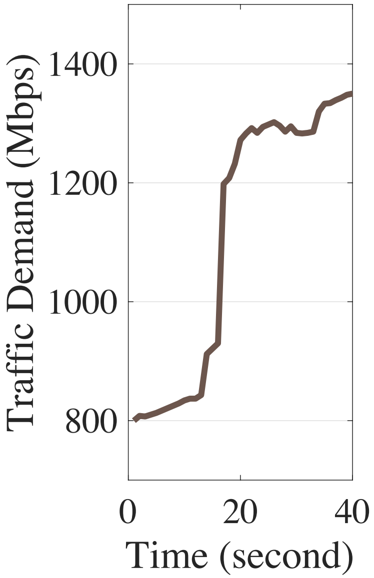
Implementation

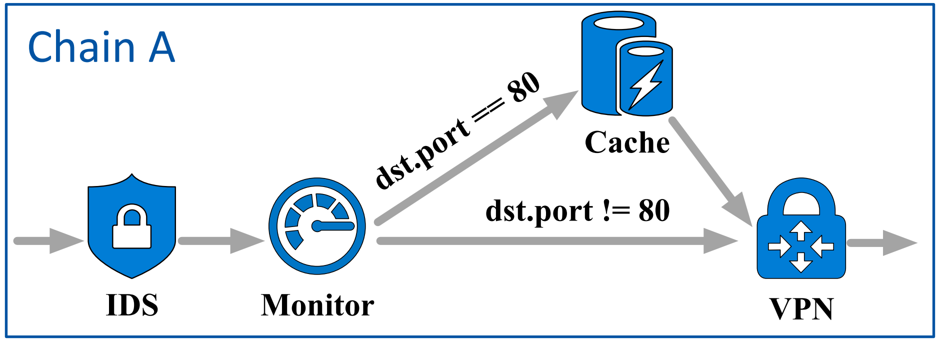
- **CASD prototype**
  - OpenNetVM and DPDK
  - TensorFlow
  - Controller loading training model
- **Two Chains**
- **Two types of traffic patterns**
  - Moderate Increase
  - Sharp Increase

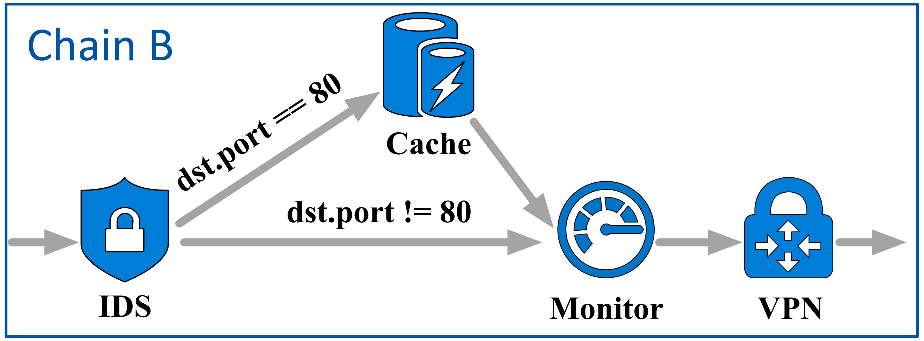


Moderate Increase



Sharp Increase





Implementation

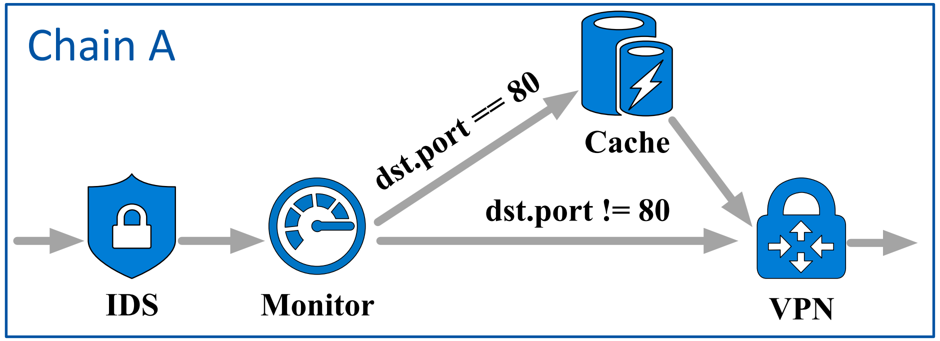
- **Status-NN**
  - Trained with RL
  - Online status
  - ENVI
- **Composite-NN**
  - Trained with RL
  - Online status + traffic rate
- **Composite-DT**
  - Decision tree
  - Online status + traffic rate

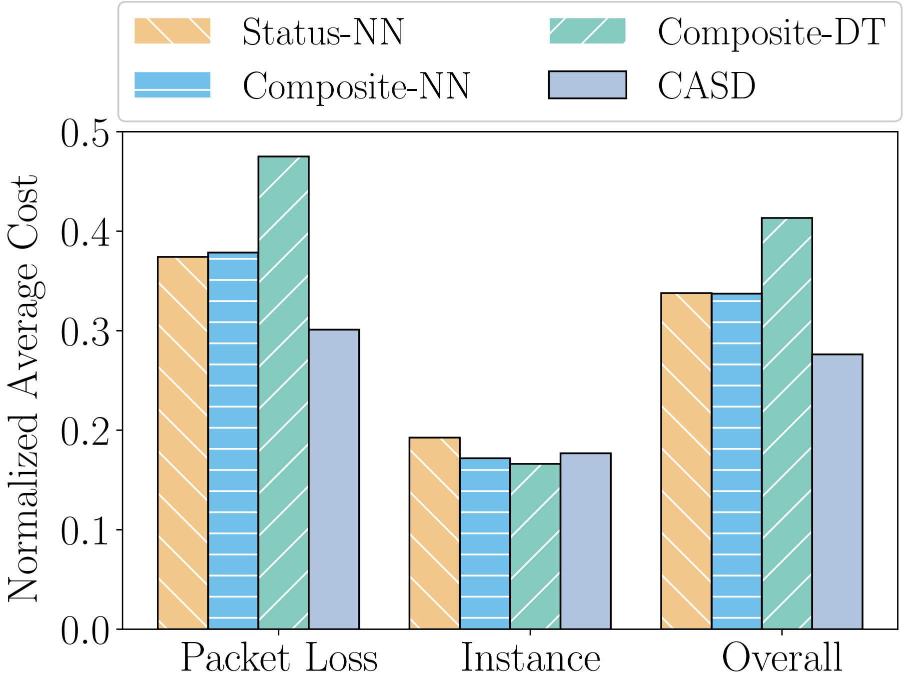
Evaluation

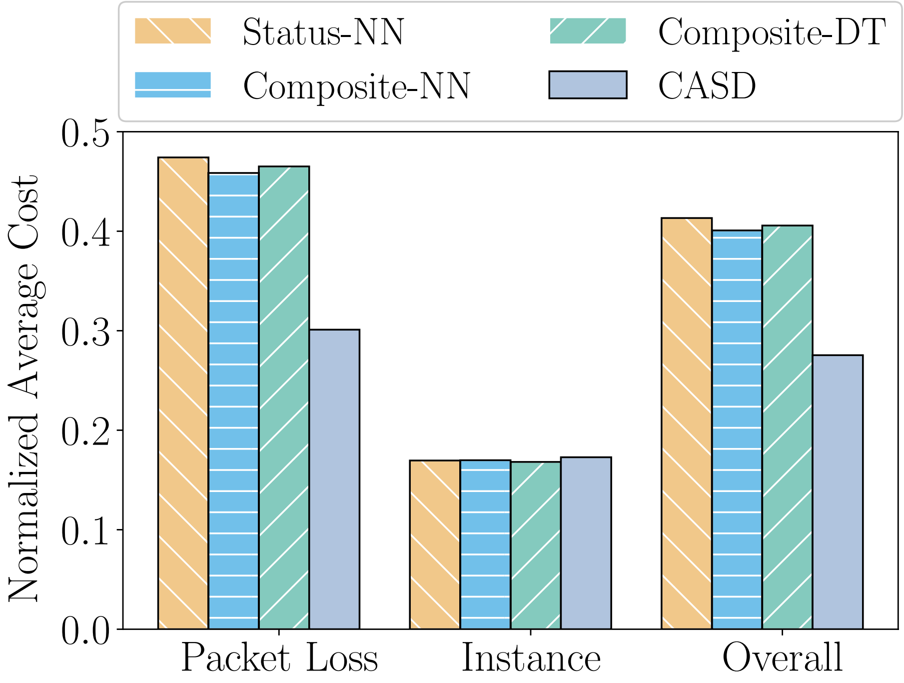
- **Overall Cost =**

  Packet Loss ↑ + Instance Cost ↑

  (Too Early) (Too Late)







Evaluation

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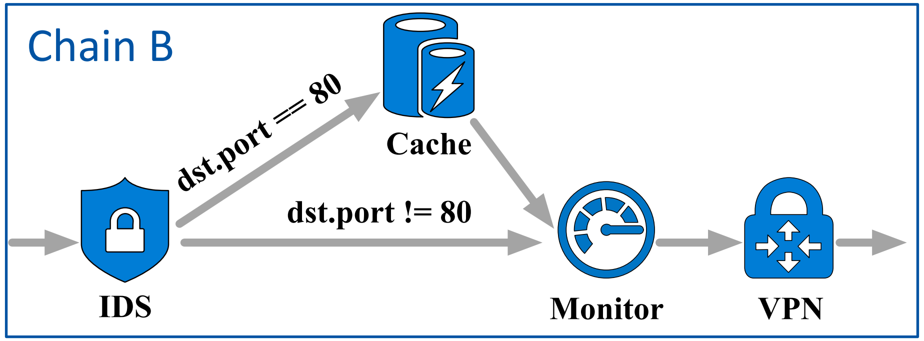
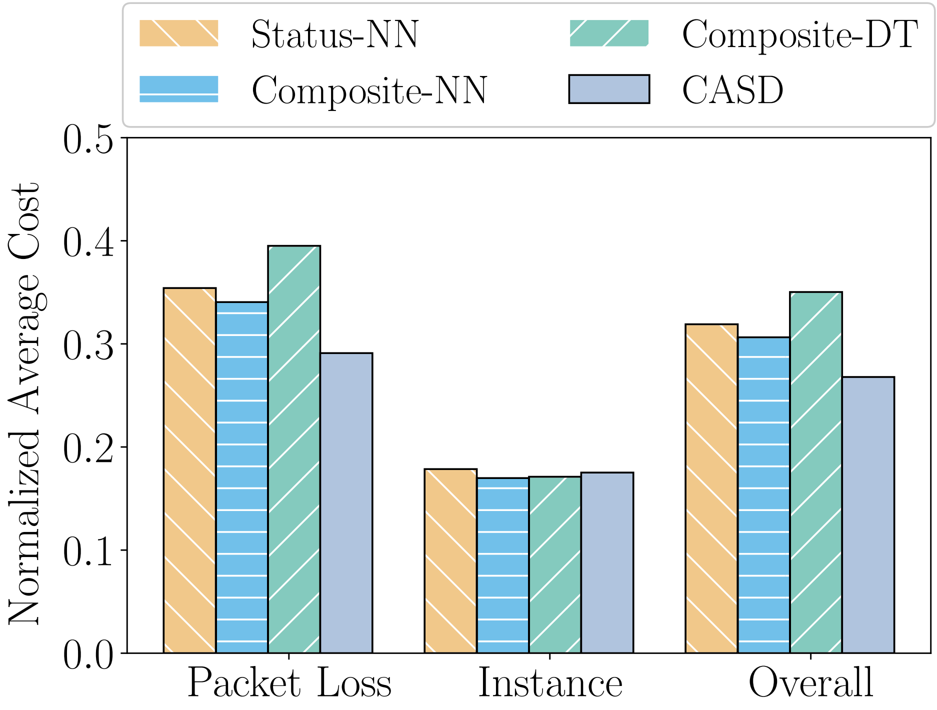
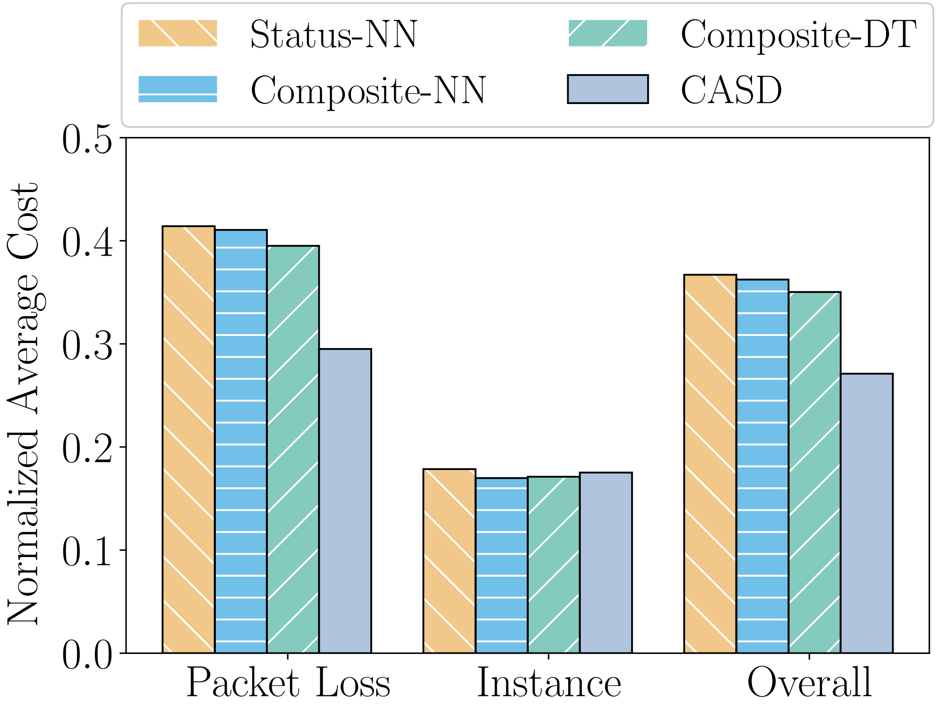
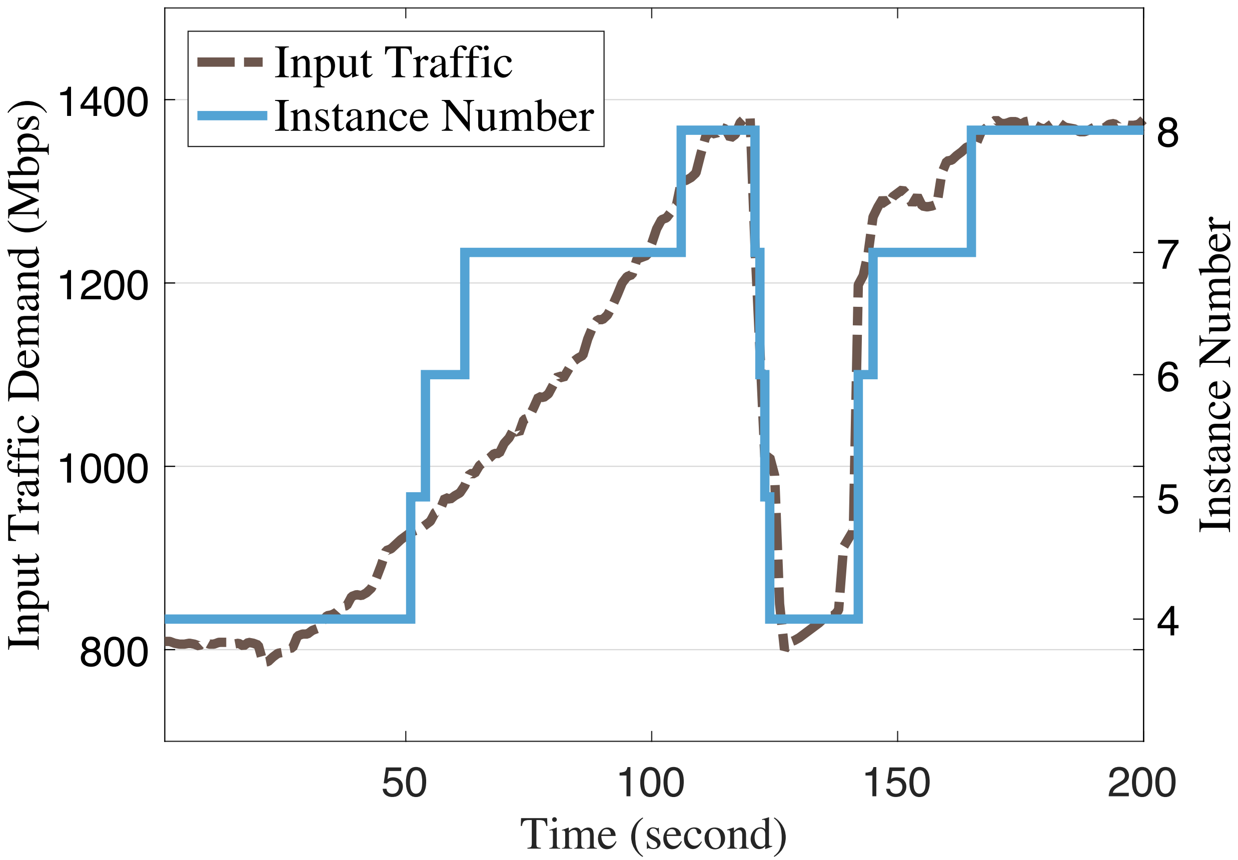






Evaluation

- **CASD Working Process**
  - Dynamic change in traffic rate → Add/remove instances



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Conclusion

- **We present CASD which utilizes reinforcement learning and neural networks to automatically learn scaling detection policies without any human instructions.**
  - To further improve agility and system performance, CASD incorporates global chain information into control policies to efficiently plan the scaling sequence of VNFs within the chain.
  - To build CASD, we develop scalable representations for VNFs and global chain, design neural networks based on feature sequence, and utilize the A3C algorithm for model training.
  - We have implemented a prototype on top of the NFV system and compare it with multiple baseline algorithms over different traffic patterns and chains.
  - Evaluation results show that CASD outperforms the state of the arts in terms of overall system cost and packet processing rate.

Thanks!