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A Virtual Service Placement Approach Based on Improved Quantum Genetic Algorithm

National Digital Switching System Engineering & Technology Research Center, Zhengzhou 450002, China

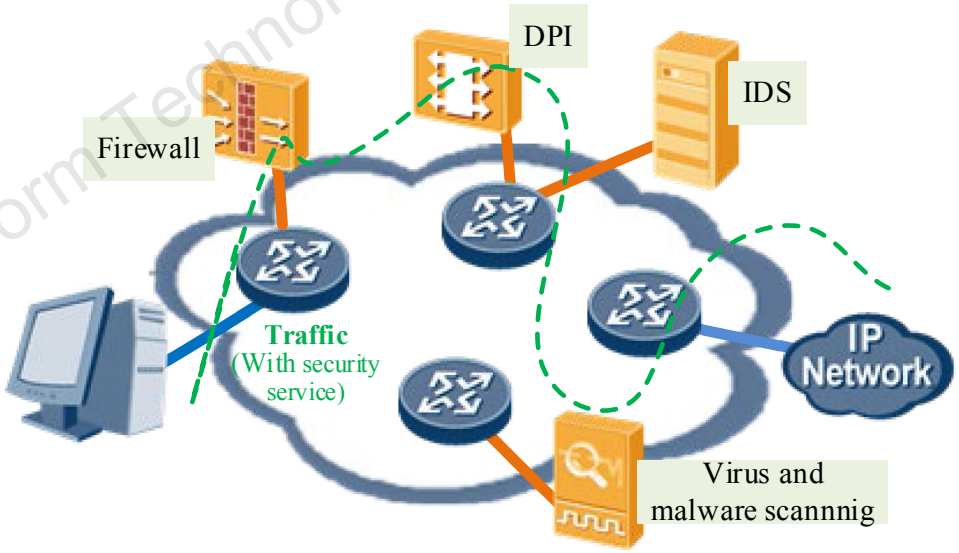
Key words: Software-defined networking, Network function virtualization, Quantum genetic algorithm, Middlebox

Contact: Gang Xiong
E-mail: xg1226@126.com
ORCID: https://orcid.org/0000-0002-4249-6820

Traditional Middleboxes Service

- Infrastructure providers build substrate network .
- Service providers deploy different middleboxes (e.g., Firewall, IDS) to provide security service for the traffics of users.

Disadvantages
- high cost
- limited flexibility
- long cycles
- ……

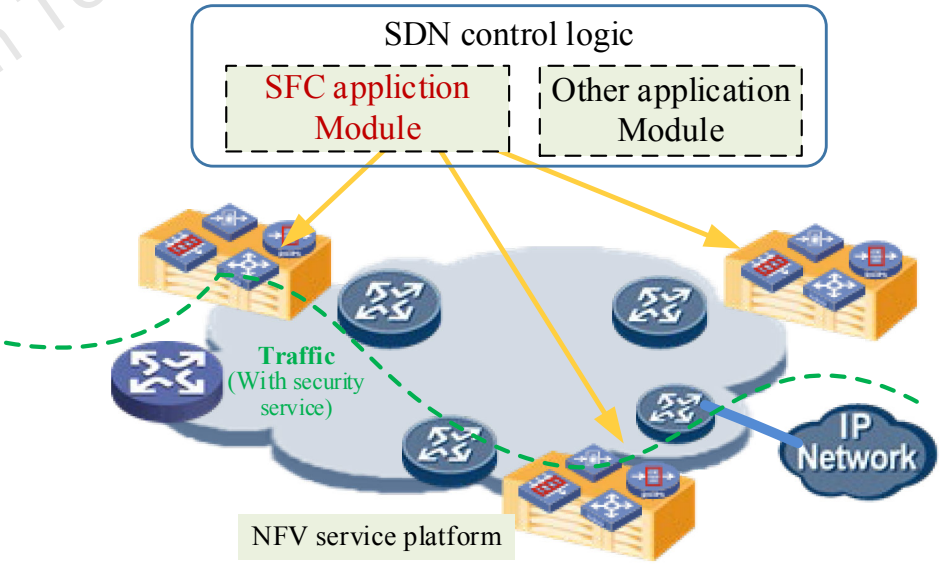


Virtual Middleboxes Service

- NFV (Network Functions Virtualization): proposes to run the network functions as software instances on commodity
- SDN (Software-Defined Networking): supports a decomposition of the network into control-plane and data-plane functions

Advantages

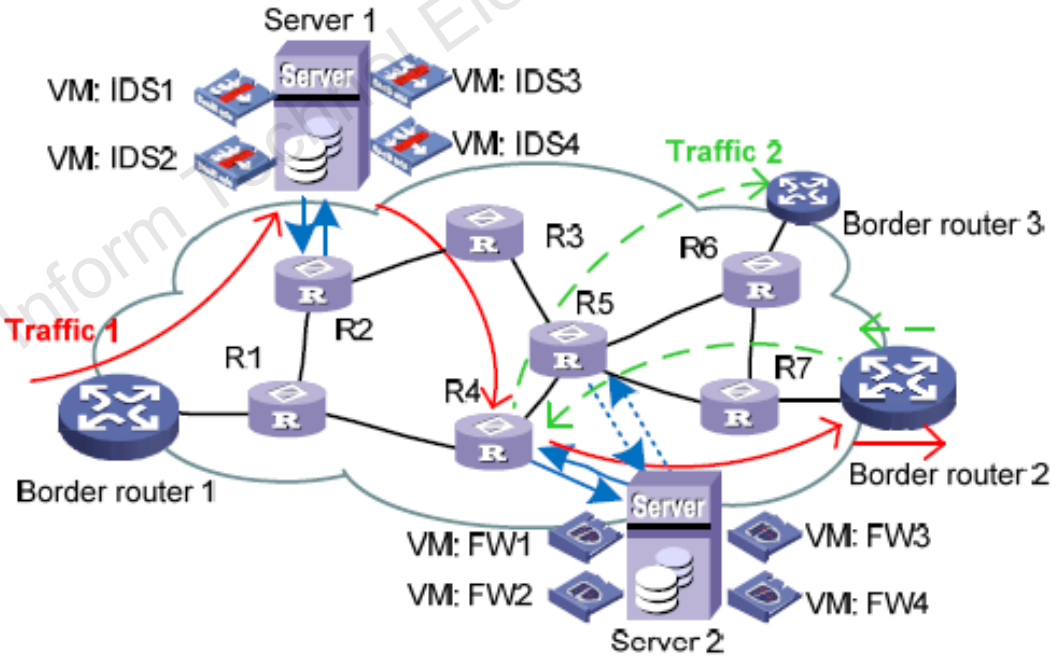
- cost reduction,
- scalability
- flexibility
- ……



Motivation

- Service Placement Problem:
  - ✓where do we connect these middlebox services so that this network performance (such as delay) penalty is minimized.

Scheme1：
{R2，R4}



✓ **Scheme2：**
{R2，R5}

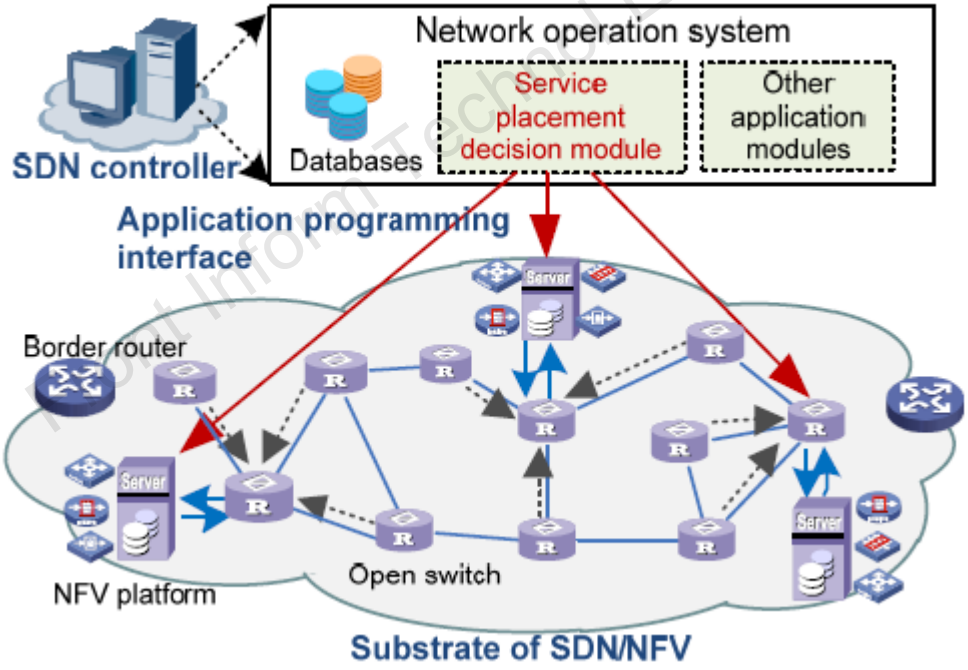
Related Work

- Existing middleboxes placement: not consider network topology
  - ✓SIMPLE: [Qazi *et al.*, 2013]
  - ✓StEERING: [Zhang *et al.*, 2013]
- Traditional agent placement: short in Performance
  - ✓On the selection of management/monitoring nodes in highly dynamic networks[J]. IEEE Trans. on Computers, [Clegg R.G., 2013]
  - ✓Towards an information management overlay for emerging networks[C]. [Mamatas L., 2010]

The *Proposed* framework

1. System overview based on SDN +NFV

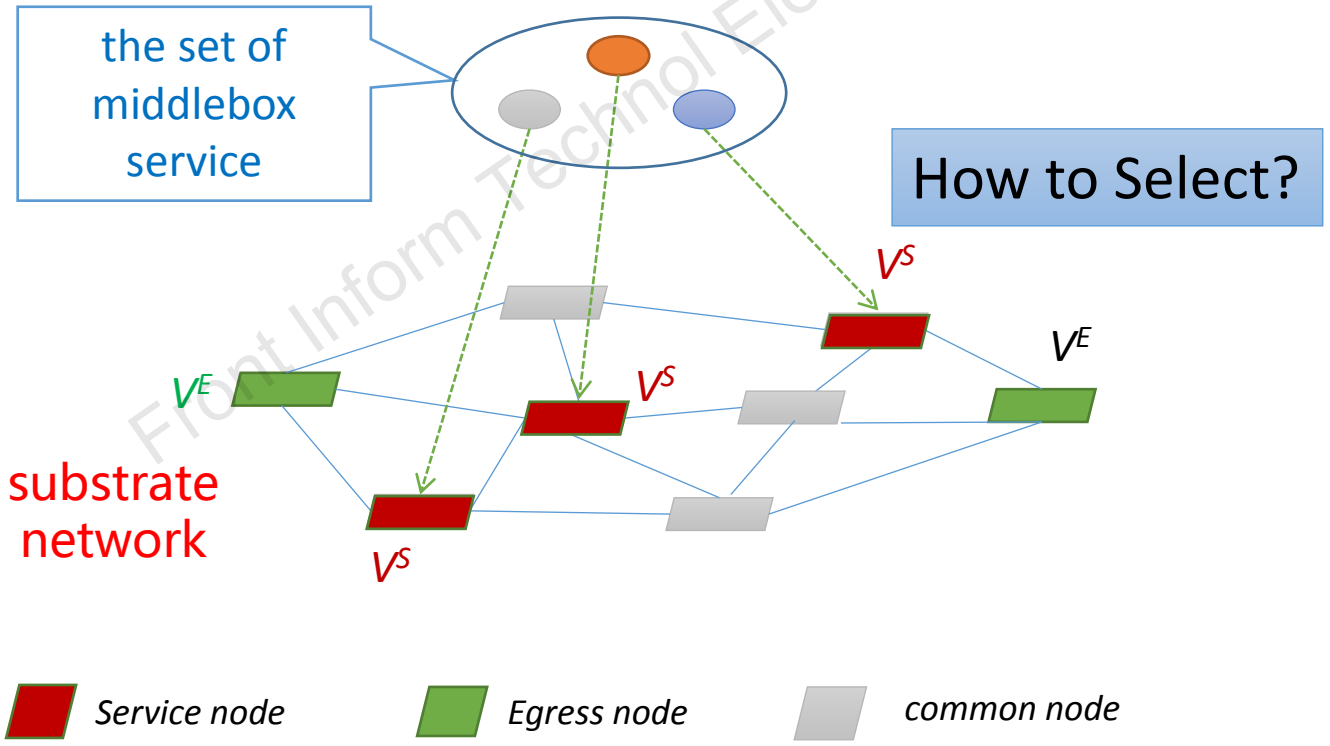
- ✓The control plane is based on the SDN controller (such as ONOS)
- ✓The data plane is based on the NFV platform (such as clickos)



The *Proposed* framework

2. Mathematical model for the service location selection

- ✓Modeling by integer linear programming
- ✓Solving by improved quantum genetic algorithm



2. Mathematical model for the service location selection

- Modeling by integer linear programming

✓**Variables:**

- Service location variable $x_i = \{0,1\}, i = 1,2,\ldots,N.$

✓**Objective:** find *the minimum total transport delay* under the optimal location solution

$$\min \sum_{i=1}^{N} x_i d\left(v_i, v_i^{\mathrm{E}}\right) + \sum_{i=1}^{N} (1 - x_i) d\left(v_i, v_i^{\mathrm{S}}\right)$$

✓**Constraints:**

- Service location constraint

$$v_i^{\mathrm{S}} = \{v_n \mid v_n \in V, x_n = 1,\ d(v_i, v_n) = \arg \min_{j \in N, x_j = 1} d(v_i, v_j)\}, \forall v_i \in V;$$

- Egress location constraint

$$v_i^{\mathrm{E}} = \{v_k \mid v_k \in V^{\mathrm{E}},\ \ d(v_i, v_k) = \arg \min_{v_j \in V^{\mathrm{E}}} d(v_i, v_j)\}, \forall v_i \in V;$$

2. Mathematical model for the service location selection

- Solving by improved quantum genetic algorithm

① Getting the shortest path matrix $\boldsymbol{D}=\left[d\left(v_i,v_j\right)\right]_{N\times N}$

② Initialization of algorithm

$$\left|\psi\right\rangle=\alpha\left|0\right\rangle+\beta\left|1\right\rangle,\alpha^2+\beta^2=1 \qquad C=\begin{array}{c}\begin{matrix}\psi_1 & \psi_2 & \cdots & \psi_N\end{matrix}\\ \left[\begin{array}{c|c|c|c}\alpha_1 & \alpha_2 & \ldots & \alpha_N\\ \beta_1 & \beta_2 & \ldots & \beta_N\end{array}\right]\end{array}$$

③ Measuring the observation value

$$X_C=\left\{x_1,x_2,\ldots,x_N\right\}$$

④ Fitness calculation

$$Fit\left(X_C\right)=\left[\sum_{i=1}^{N}x_i d\left(v_i,v_i^{\mathrm{E}}\right)+\sum_{i=1}^{N}\left(1-x_i\right)d\left(v_i,v_i^{\mathrm{S}}\right)\right]^{-1}$$

⑤ Adaptive adjustment

$$\begin{bmatrix}\alpha'_{mi}\\ \beta'_{mi}\end{bmatrix}=\boldsymbol{U}\left(\theta\right)\begin{bmatrix}\alpha_{mi}\\ \beta_{mi}\end{bmatrix}=\begin{bmatrix}\cos\theta_i & -\sin\theta_i\\ \sin\theta_i & \cos\theta_i\end{bmatrix}\begin{bmatrix}\alpha_{mi}\\ \beta_{mi}\end{bmatrix}$$

⑥ Quantum variation and quantum crossover

Simulation Setup

- Experimental environment
  - ✓*a computer equipped with an Intel(R) Core(TM) i7 CPU 2.67 GHz processor with 2 cores, and 4 GB RAM.*
  - ✓*The GT-ITM Tool is used for generating different network topologies*
- Performance metrics
  - ✓ *overall delay of network traffic*
  - ✓ *the average delay of each flow*

Results: Comparison of algorithms

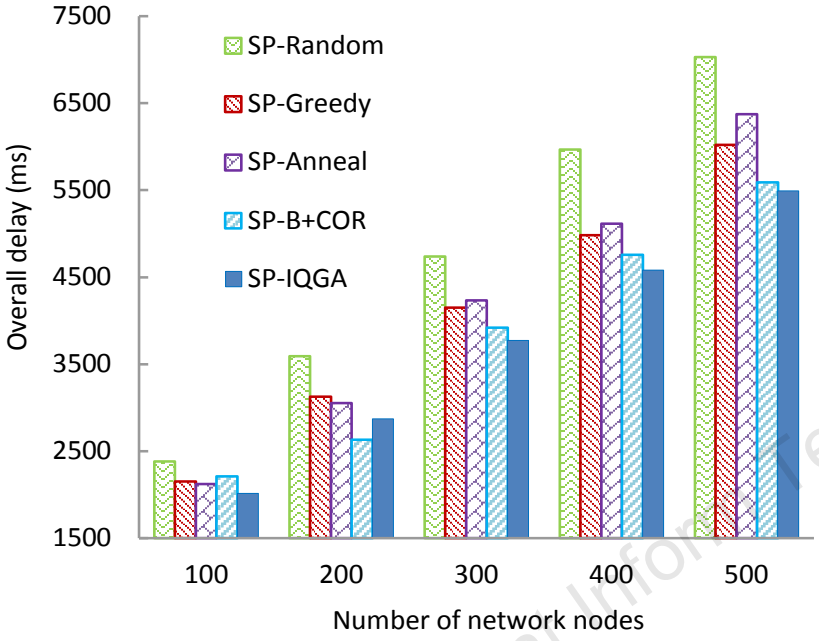


Fig. 7 Overall transport delay comparison under different network sizes

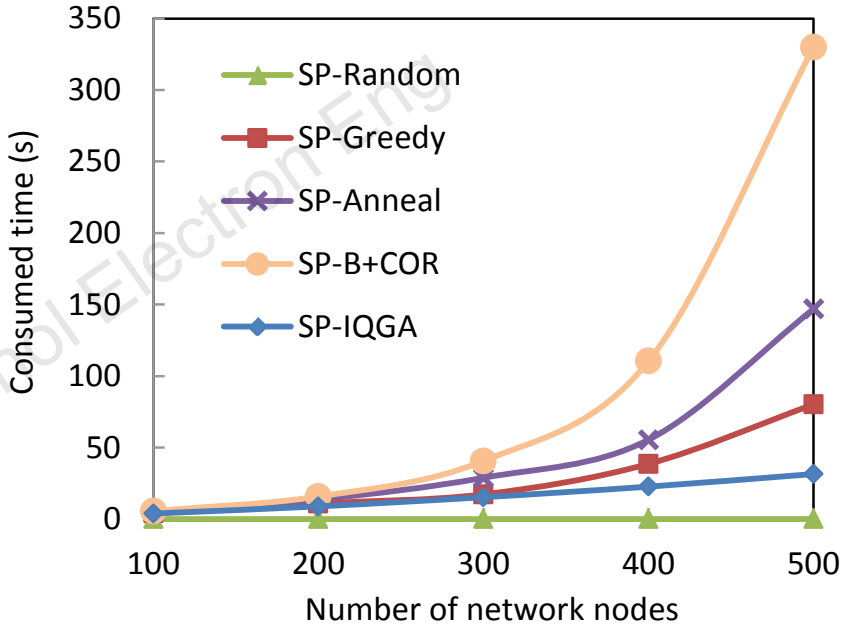


Fig. 8 Time cost comparison under different network sizes

Results: Comparison of algorithms

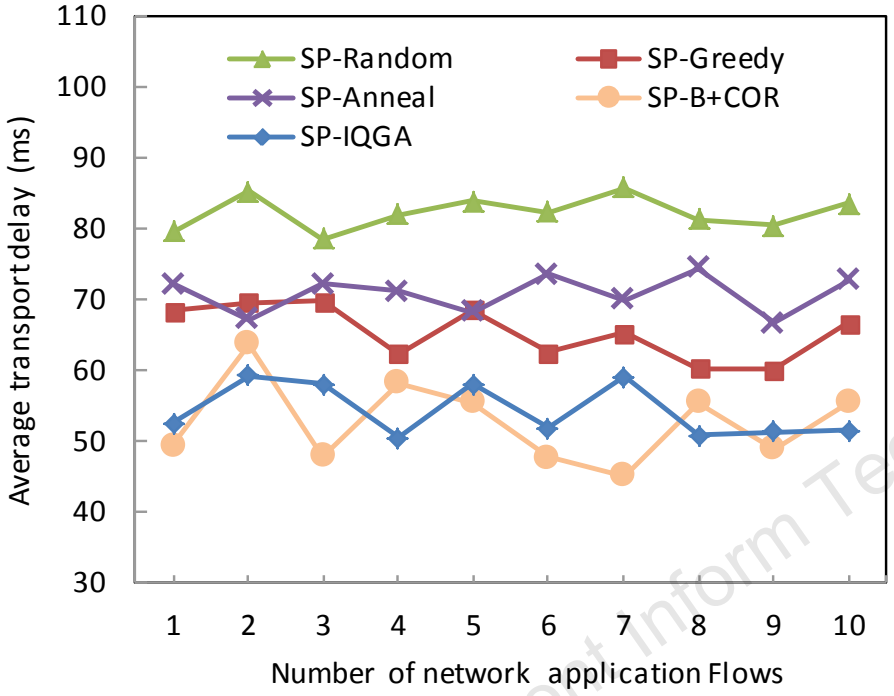


Fig. 9 Average transport delay comparison under different flows

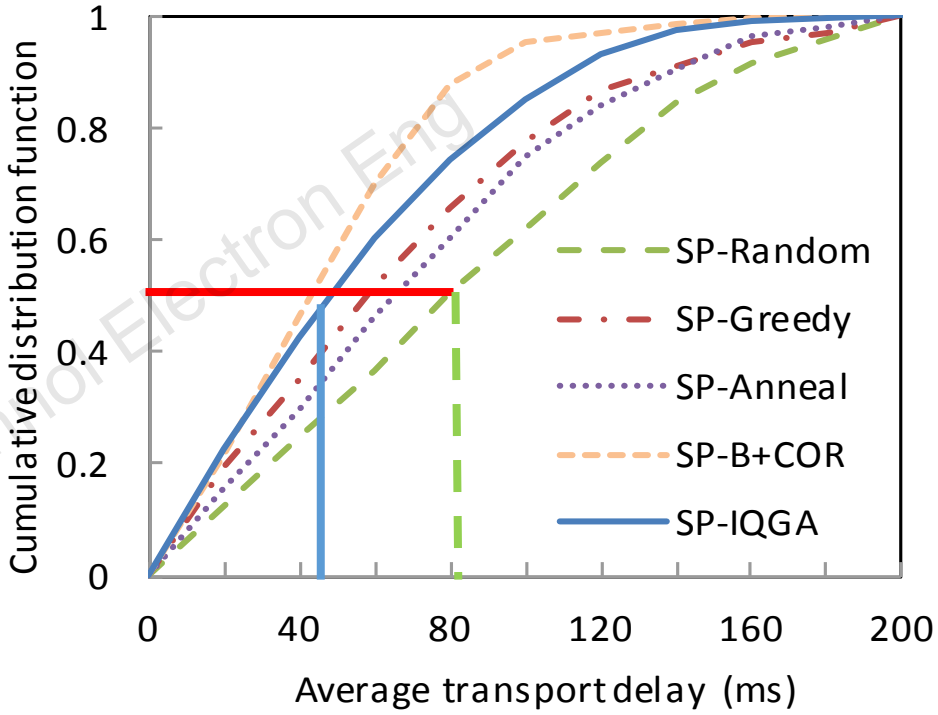


Fig. 10 Transport delay distribution of different strategies

Conclusions

- We re-examined the virtual middlebox placement problem from the aspect
  - ✓Reducing the overall delay of traffic

- We proposed a placement framework, which contains two main components
  - ✓System overview based on SDN+NFV
  - ✓ Service location selection algorithm