

Gang Xiong, Yu-xiang Hu, Ju-long Lan, Jun-fei Li, Qiao Zhou, 2016.

A virtual service placement approach based on improved quantum genetic algorithm. *Frontiers of Information Technology & Electronic Engineering*, 17(7):661-671. <http://dx.doi.org/10.1631/FITEE.1500494>

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

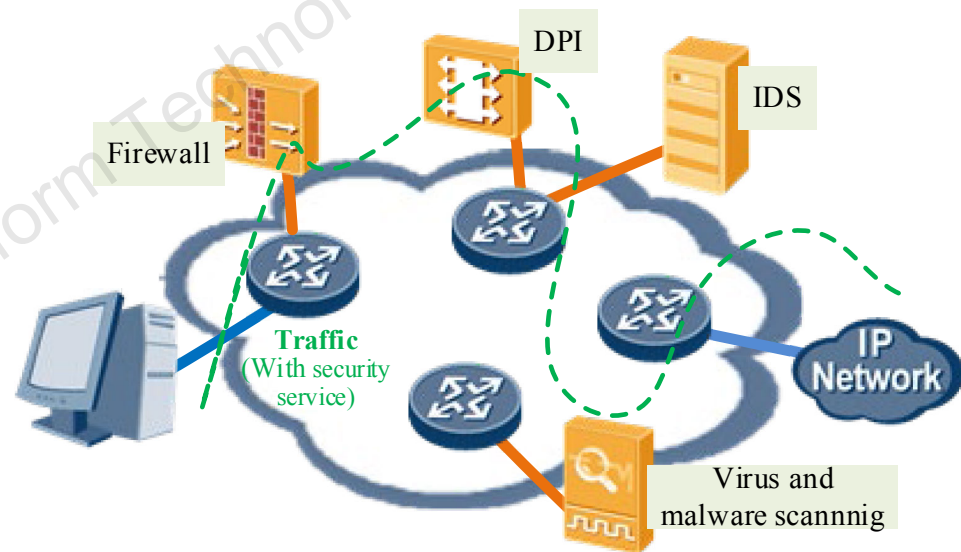
 ORCID: <https://orcid.org/0000-0002-4249-6820>

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
-

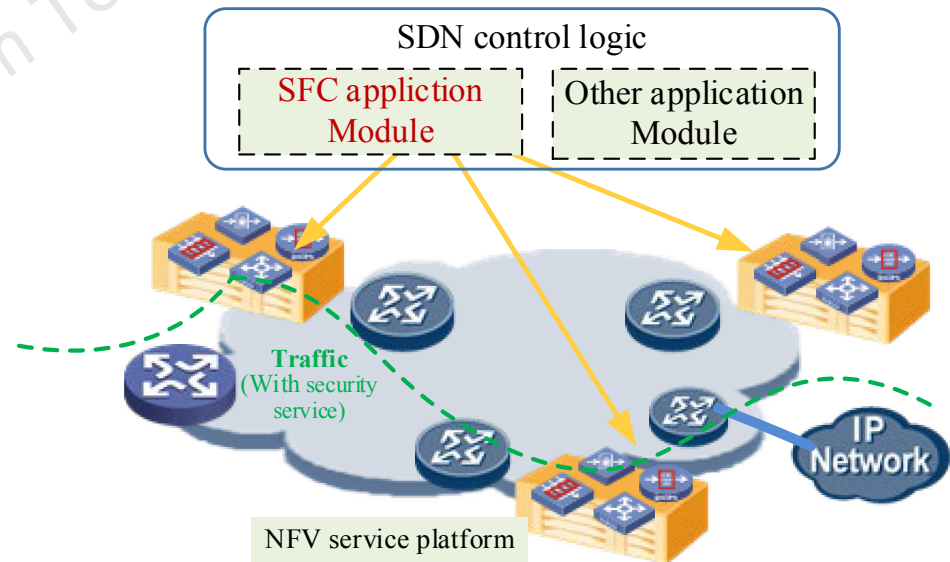


Virtual Middleboxes Service

- **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
-



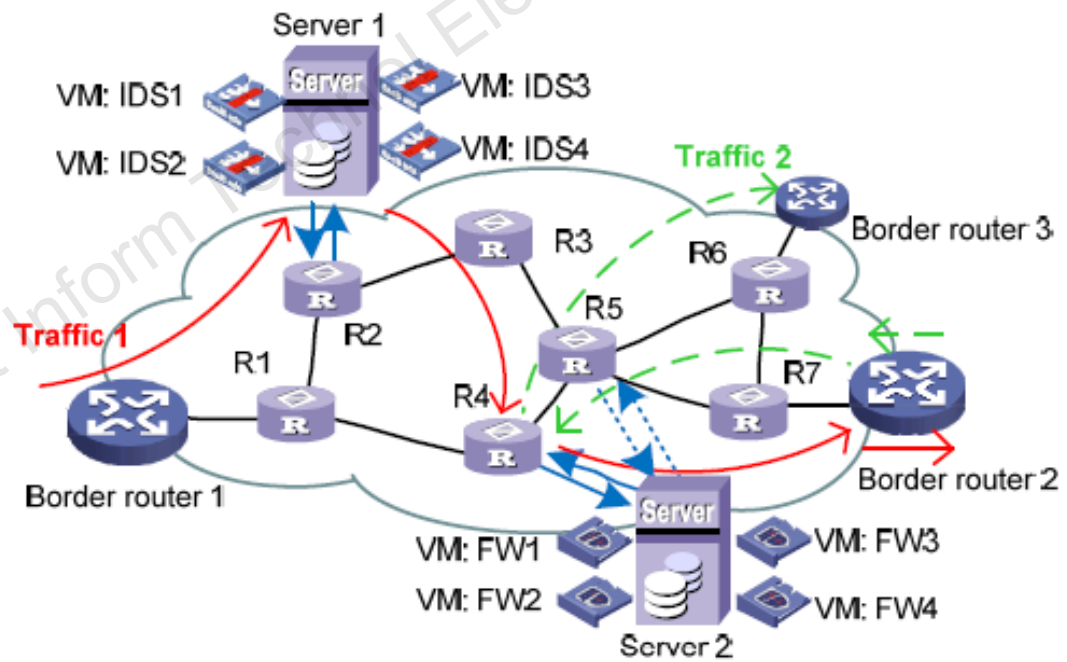
Motivation

● 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}



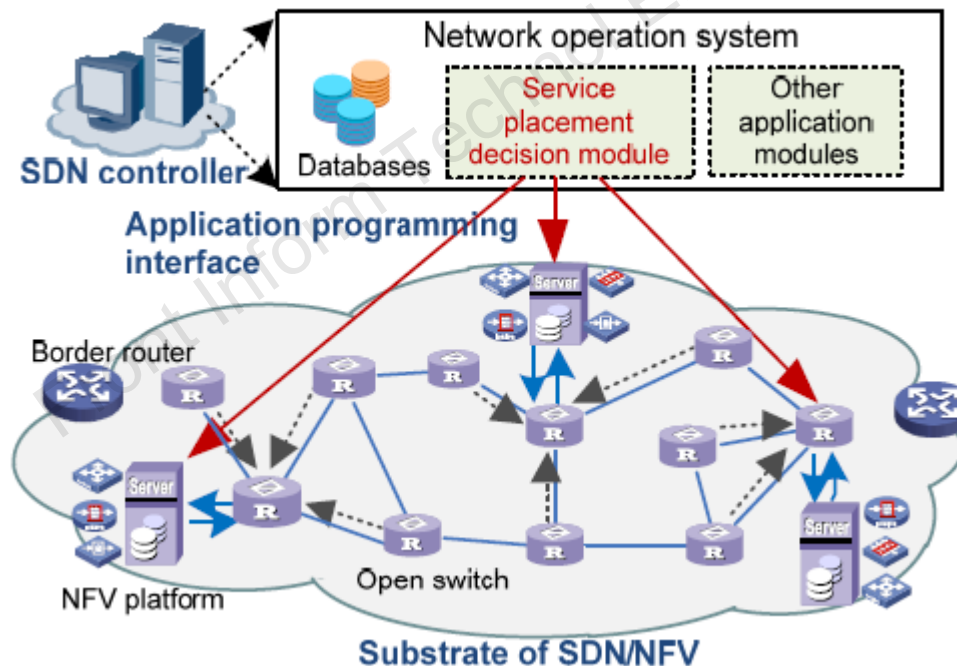
Related Work

- **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

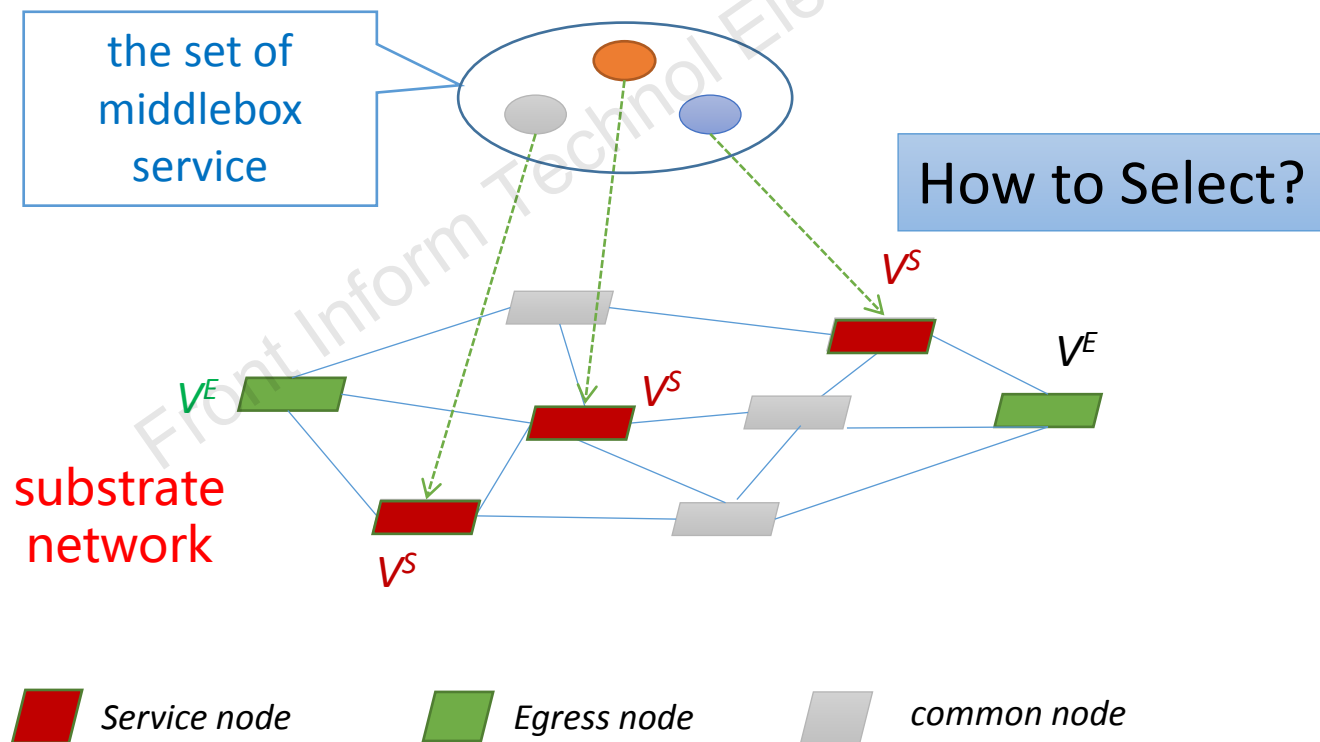
- ✓The control plane is based on the SDN controller (such as ONOS)
- ✓The data plane is based on the NFV platform (such as clickos)



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 $x_i = \{0, 1\}, i = 1, 2, \dots, N.$

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

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

✓ Constraints:

- Service location constraint

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

- Egress location constraint

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

2. Mathematical model for the service location selection

● Solving by improved quantum genetic algorithm

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

② Initialization of algorithm

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

③ Measuring the observation value

$$X_C = \{x_1, x_2, \dots, x_N\}$$

④ Fitness calculation

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

⑤ Adaptive adjustment

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

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

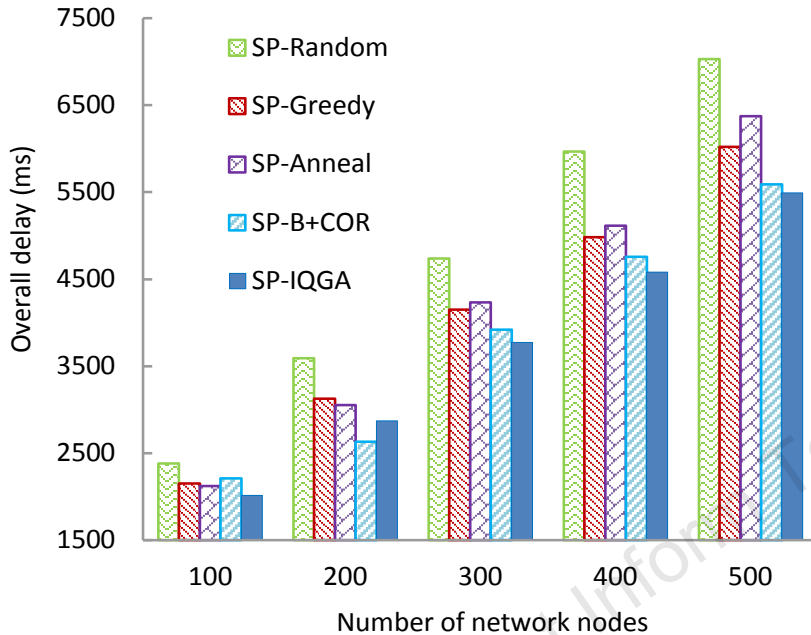


Fig. 7 Overall transport delay comparison under different network sizes

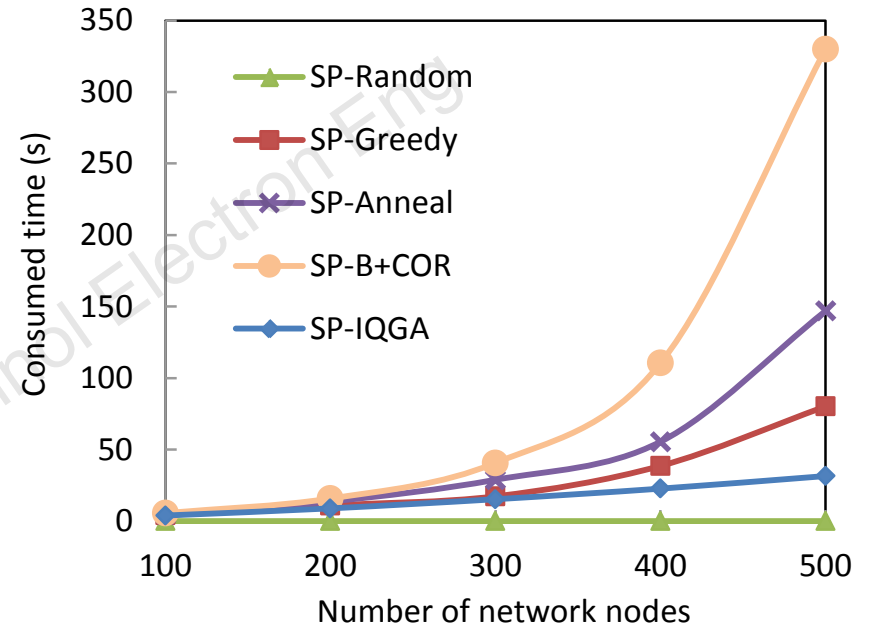


Fig. 8 Time cost comparison under different network sizes

Results: Comparison of algorithms

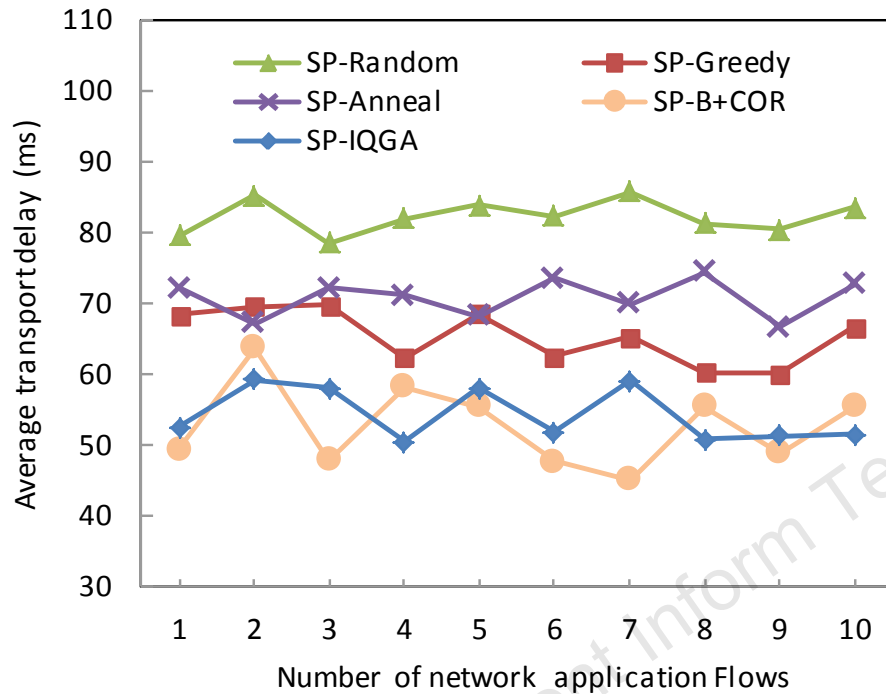


Fig. 9 Average transport delay comparison under different flows

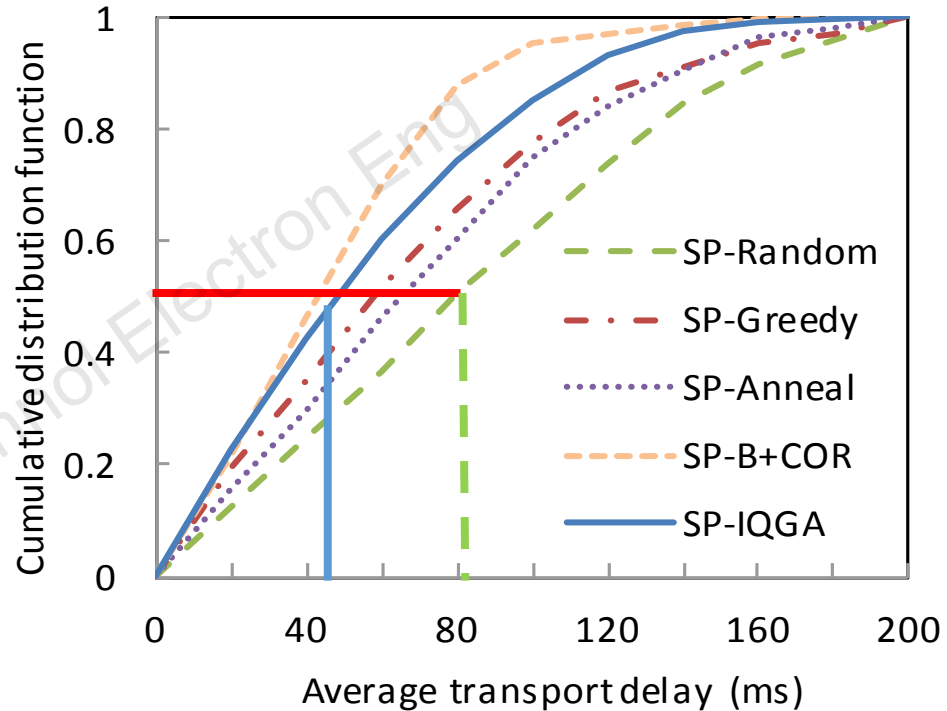


Fig. 10 Transport delay distribution of different strategies

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