Design of Optical Aggregation Network with Carrier Edge Functions Virtualization

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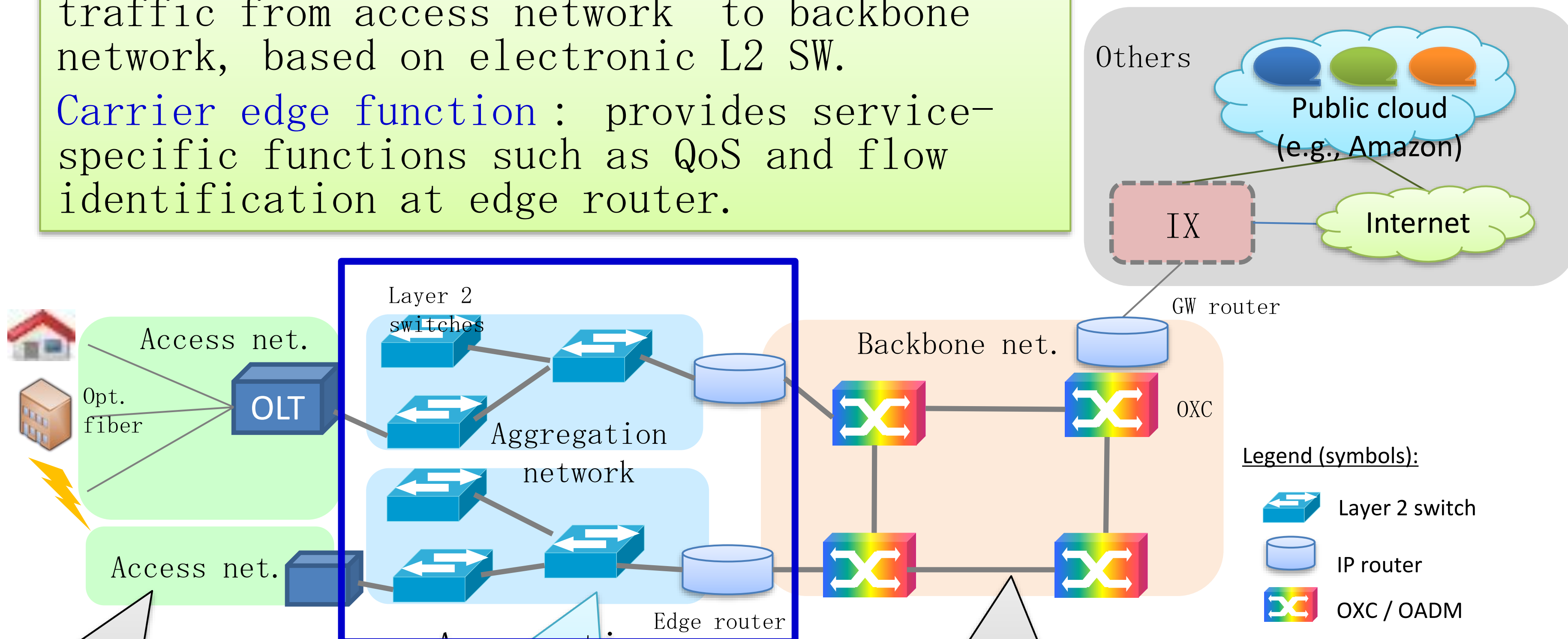
Outline

1. Background
2. Objective
3. Proposed Method
4. Performance Evaluation
5. Conclude

Outline

Carrier network architecture

Aggregation network (metro) : Transport traffic from access network to backbone network, based on electronic L2 SW.
Carrier edge function : provides service-specific functions such as QoS and flow identification at edge router.



Access network: Connecting user premises with carrier network

Aggregation network : Concentrate user traffic and transport it to the backbone

Backbone network : Transport long-haul traffic

※OLT: Optical Line Terminal, OXC: Optical Cross-connect

Recent trend in aggregation networks

Innovative R&D by NTT

① : Introducing NFV for Carrier Edge functions

- Edge functions to be relocated from edge routers to distributed pools of commodity servers

② : TDM/WDM-based Optical Aggregation Network

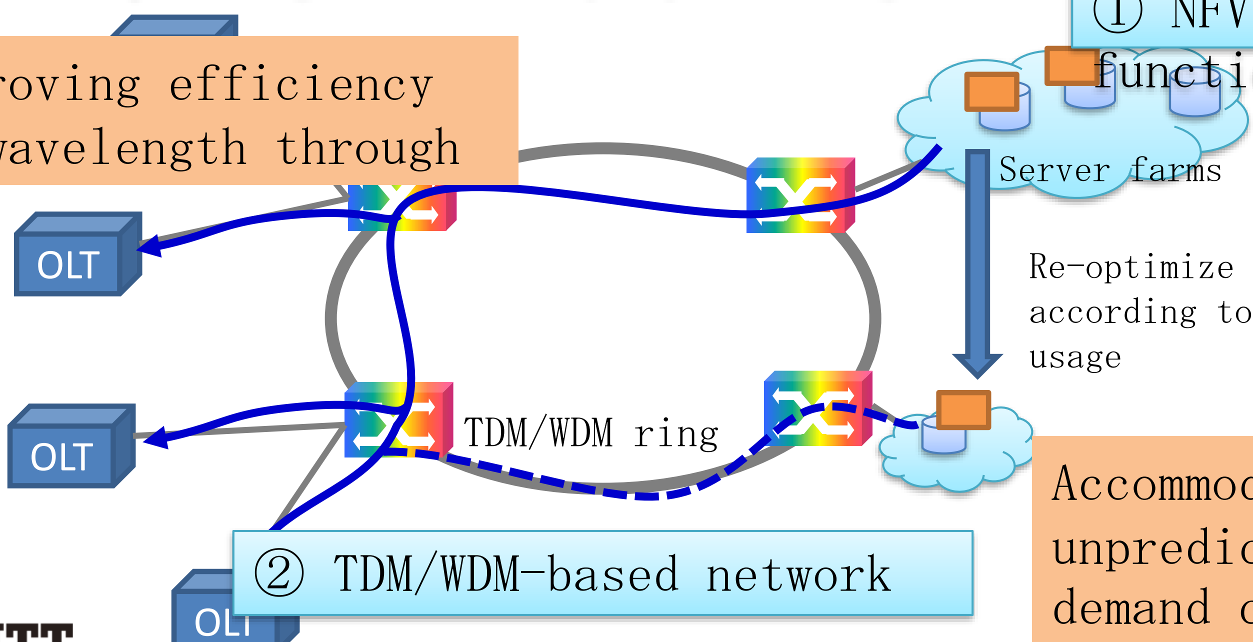
- WDM ring network to accommodate large-volume traffic efficiently

VNF: Virtual Network Function

- Improving efficiency by sharing same w

① NFV for edge functions

Improving efficiency of wavelength through TDM



Re-optimize VNF placement according to uneven resource usage

② TDM/WDM-based network

Accommodate unpredictable traffic demand changes by NFV

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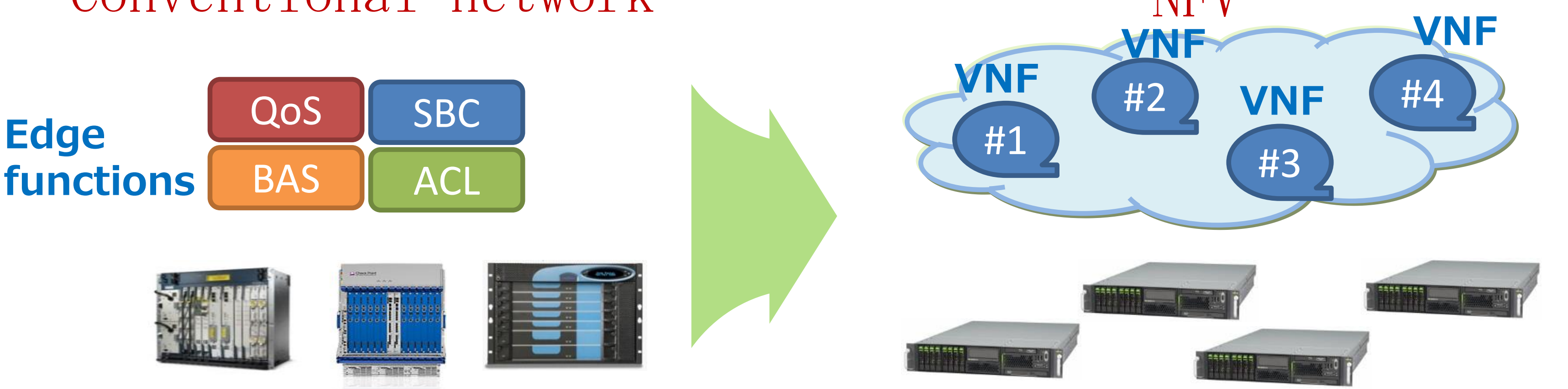
① Carrier edge functions virtualization

- Advantages:
  - Create VNF for each OLT. The VNF can be flexibly placed on any servers among distributed pools of commodity servers.
  - Can be live-migrated from an over-loaded server to an under-utilized one in response to unpredictable traffic changes.
- Challenges:
  - Determine VNF placement considering traffic demand and geographical location (e.g. distance bet. OLT-Server).

Conventional network

NFV



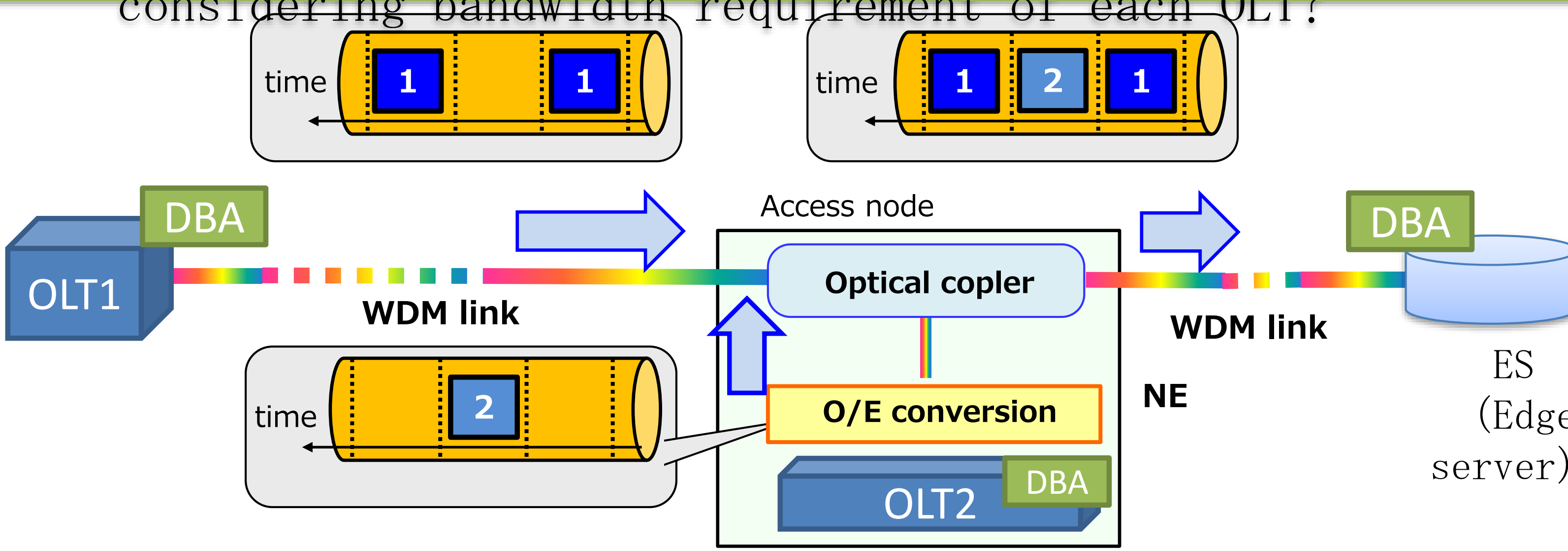
Edge routers（dedicated hardware)

Commodity servers

VNF (virtual network function): Implementation as software

② TDM/WDM-based aggregations network

- Advantages:
  - To cope with bursty traffic, enable the same wavelength channel to be shared by multiple OLTs through DBA or other TDM technologies.
- Challenges:
  - How to efficiently select route for P2MP wavelength path considering bandwidth requirement of each OLT?



[1] K. Hattori et al., IEICE Trans. Electron., Vol. E99-C, No. 2, pp. 189-201, February 2016.

Outline

Issues in carrier edge virtualization

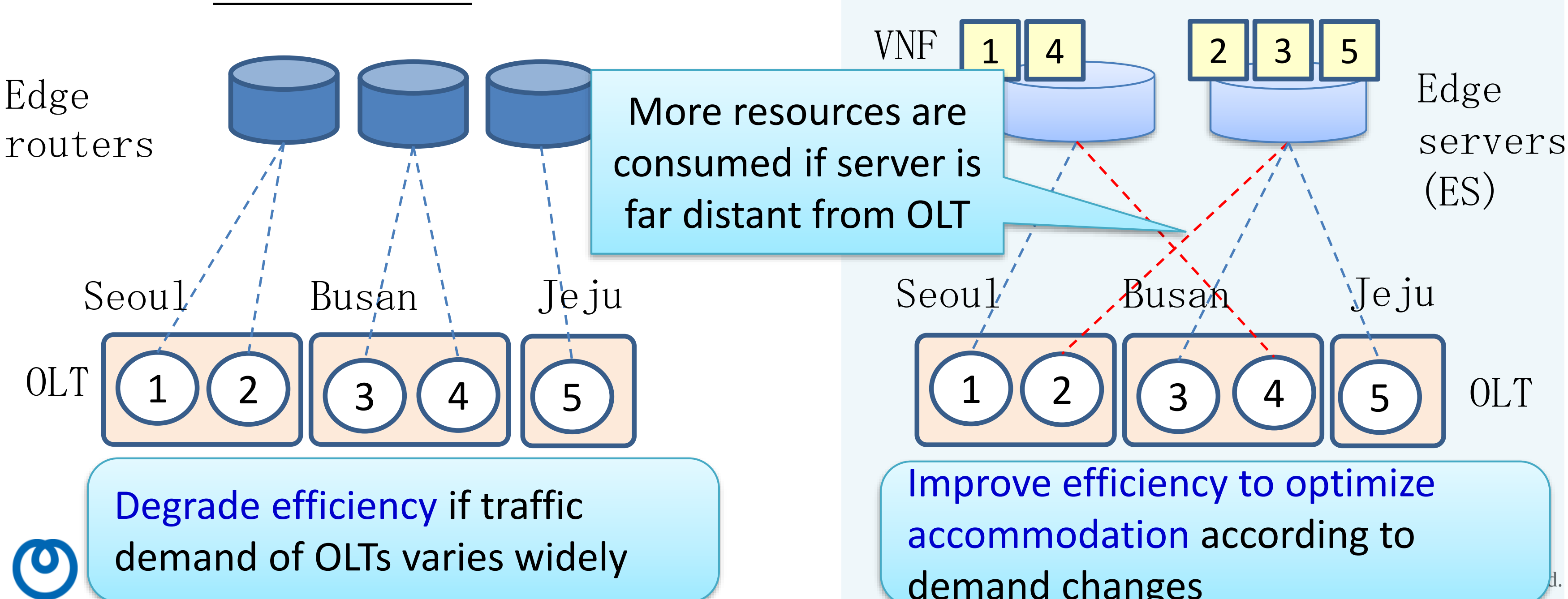
Conventional : Deployment of edge routers
- Edge routers accommodate fixed group of OLTs based on location. This causes congested or under-utilized routers due to unpredictable traffic demand changes

Our approach : NFV for carrier edge fucntions
- Can accommodate OLTs independent of location, so it can provides robustness

⇒However, consumes more network resources if we allocate VNFs on geographically remote server.

Conventional

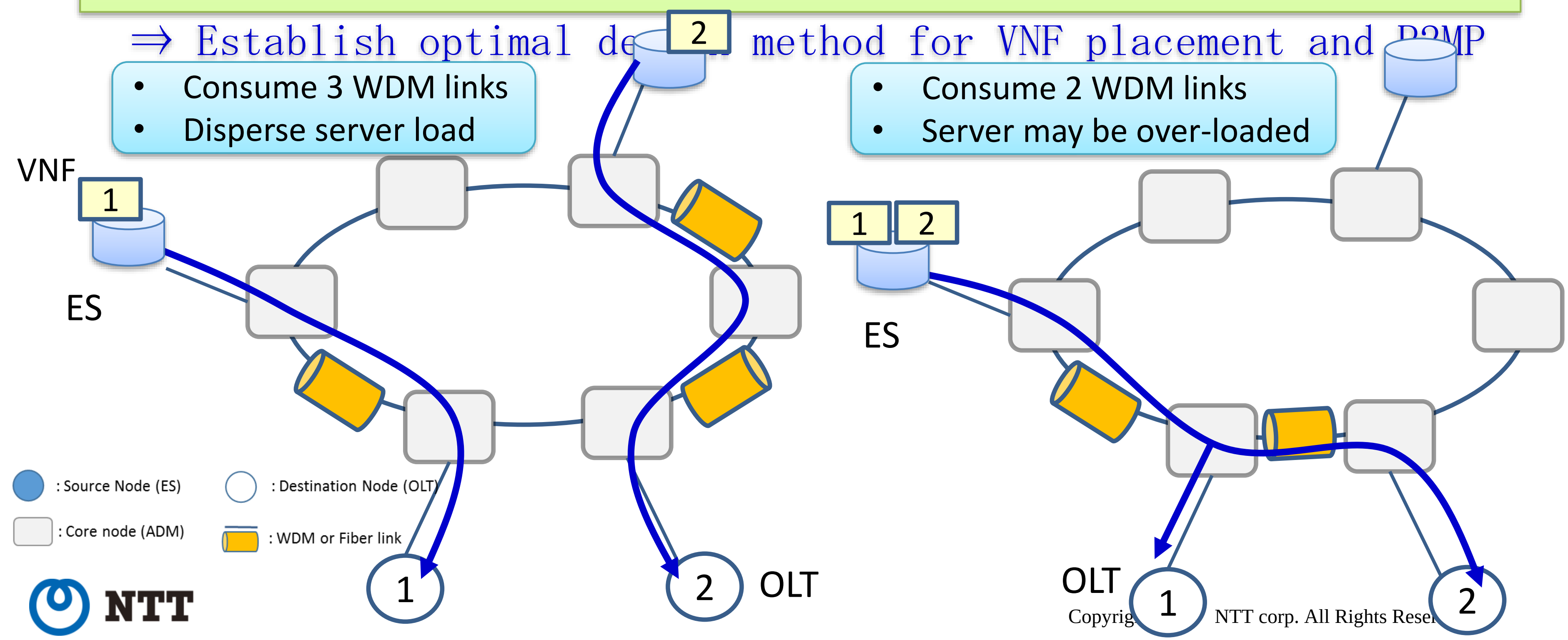
Our approach: NFV for edge functions



Objective

- Minimize network cost while efficiently utilizing server resources.
  - For optimal VNF placement, we need to consider resource requirements of optical network in addition to server resources
  - In optical aggregation network, we need to consider the sharing of wavelength paths as we can use P2MP paths connecting server and OLTs

⇒ Establish optimal de method for VNF placement and P2MP



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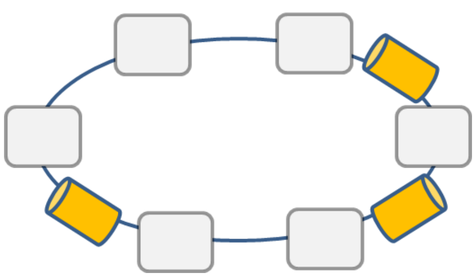
Proposed design method

We formulate the design problem as mixed integer linear programming (MILP).

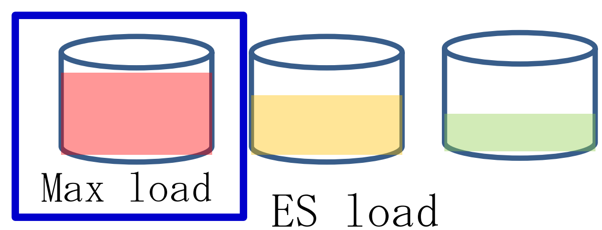
- **Objective function:**
  - Minimize weighted sum of network cost and max server load
- **Variables:**
  - P2MP wavelength paths between server and OLTs
  - VNF placement (Select ES to be accommodated)

$$\min \left(\underbrace{\sum_{k} \sum_{mn} C_{mn}^{k}}_{\text{Network cost}} + \alpha \underbrace{\max_{i} \sum_{k} \sum_{j} D_j \cdot x_{ij}^{k}}_{\text{Max server load}} \right) \qquad (1)$$

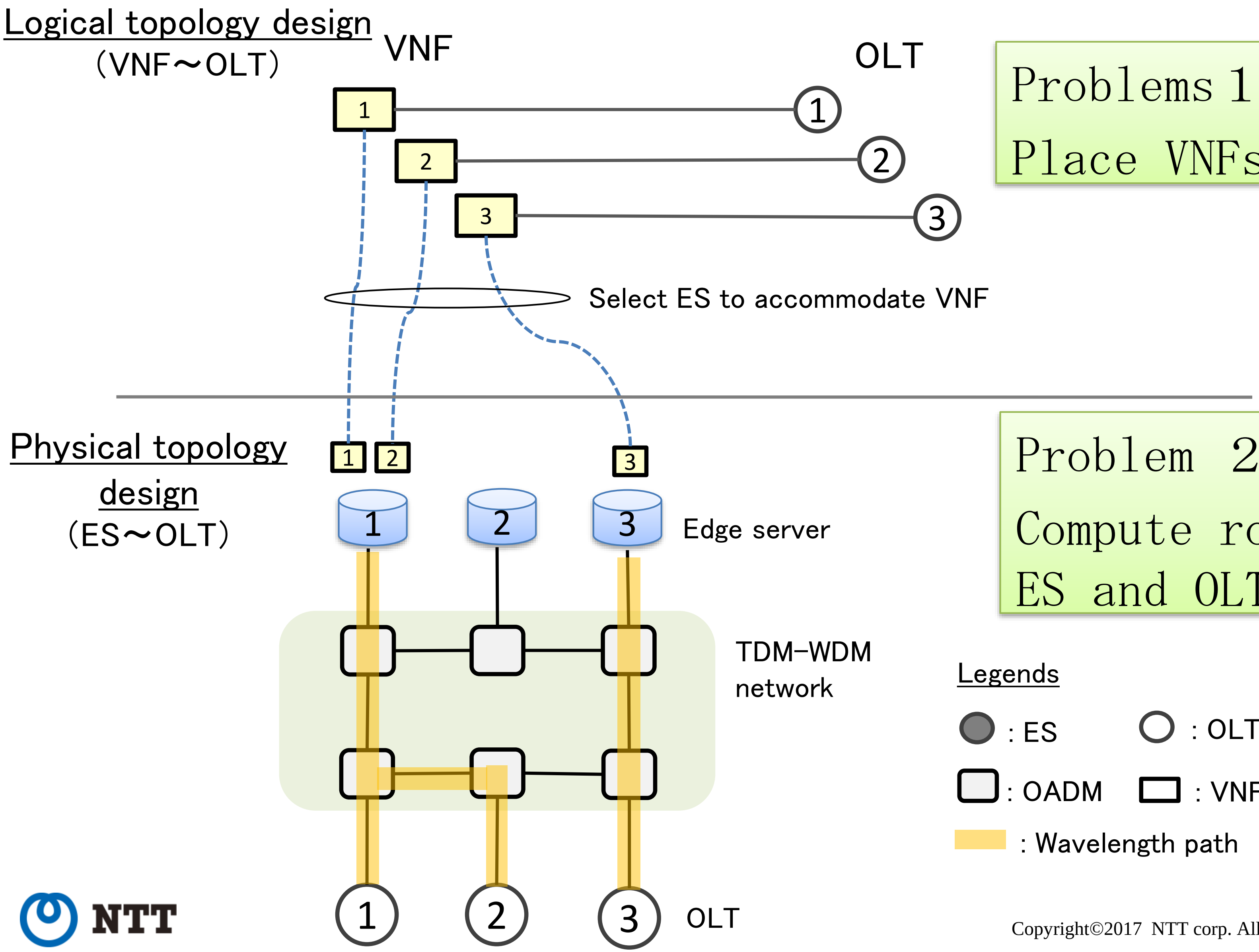
Weight parameter



Total of WDM links used for P2MP paths



Network model



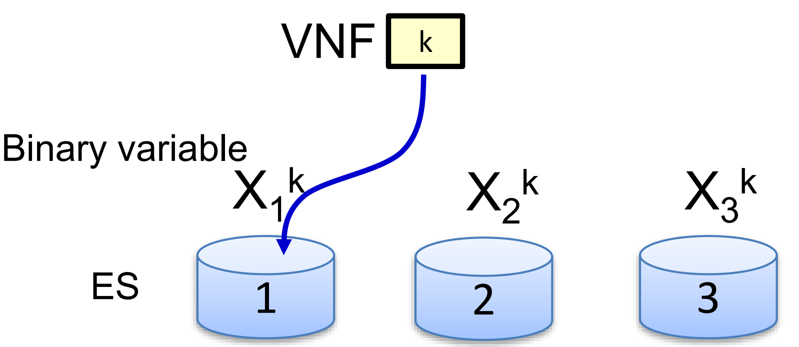
Problems 1 :
Place VNFs on ES

Problem 2 :
Compute route bet. ES and OLT.

Overview of MILP formulations

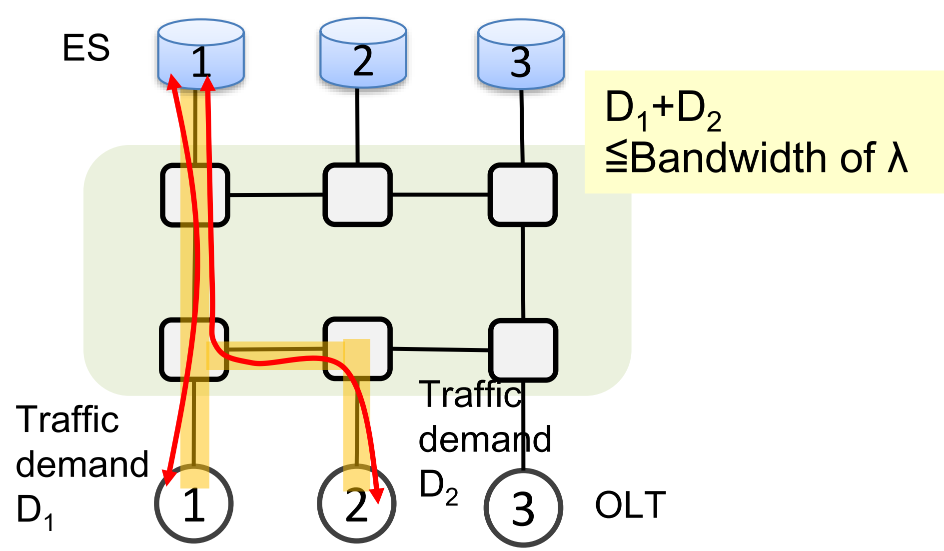
- VNF placement
  - Assign binary variables to candidate ES for VNF placement
- Route for P2MP wavelength path
  - Configure logical flow bet. VNF～OLT.
  - Find route for P2MP path minimize network cost while accommodating traffic demand of logical flows.

VNF placement



X_1^k
=1 (accommodate VNF k)
=0 (no placement)

P2MP wavelength path



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Objective of performance evaluation

①： Design of parameter α

- Parameter α governs the weight of network cost on server load

②： Effectiveness

- Effectiveness regarding reduction in network cost and server load

③： Robustness against unpredictable traffic changes

- Evaluate impact of increased variations of traffic demand

Objective function

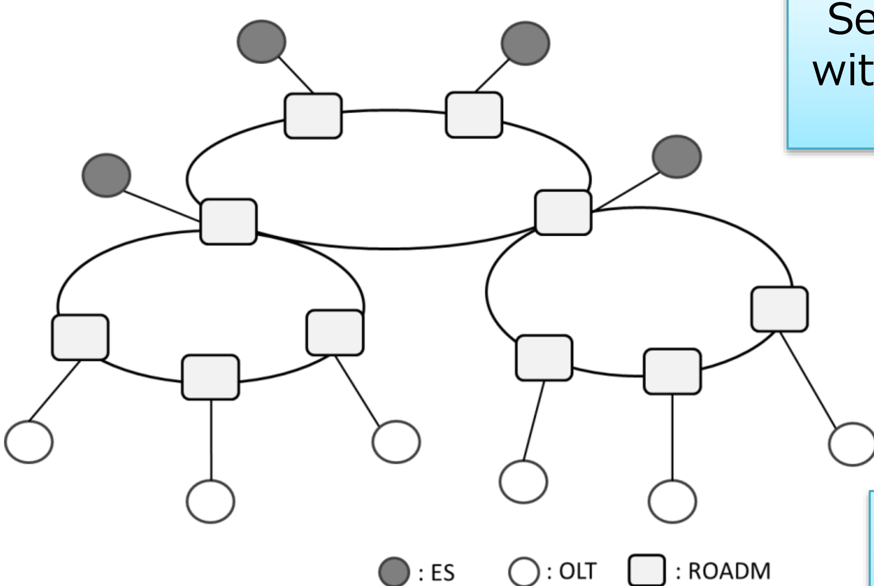
$$\min \left(\underbrace{\sum_k \sum_{mn} C^k_{mn}}_{\text{Network cost}} + \alpha \underbrace{\max_i \sum_k \sum_j D_j \cdot x^k_{ij}}_{\text{Max server load}} \right) \quad (1)$$

Wight parameter

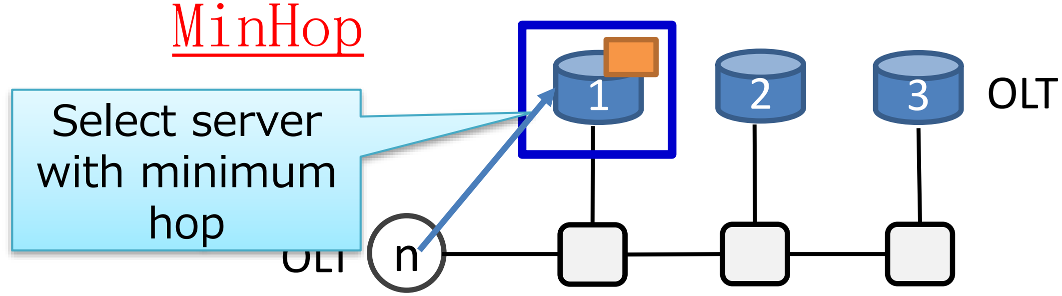
Evaluation conditions

- Topology： 10-node multi-ring
- Traffic demand： Zipf distribution $T(x)=b*x^{-\beta}$
- Reference method： MinHop, RoundRobin

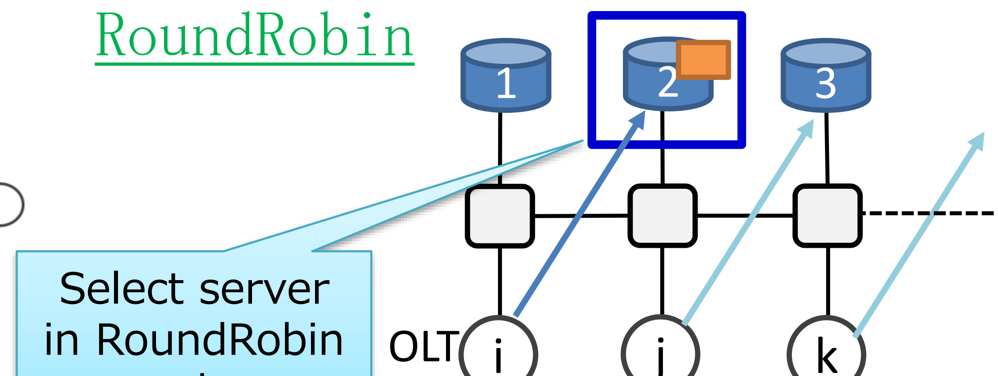
Network topology



MinHop

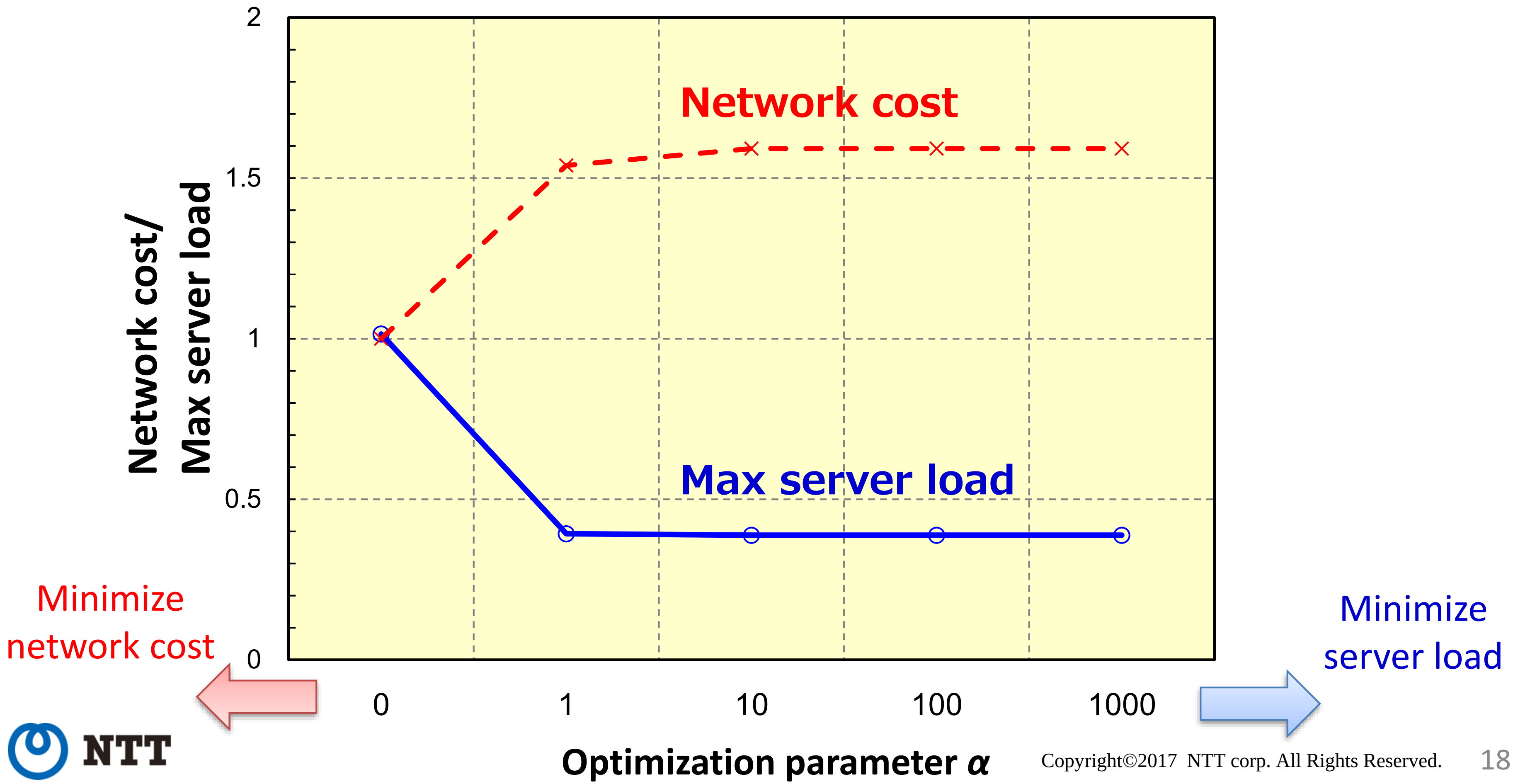


RoundRobin



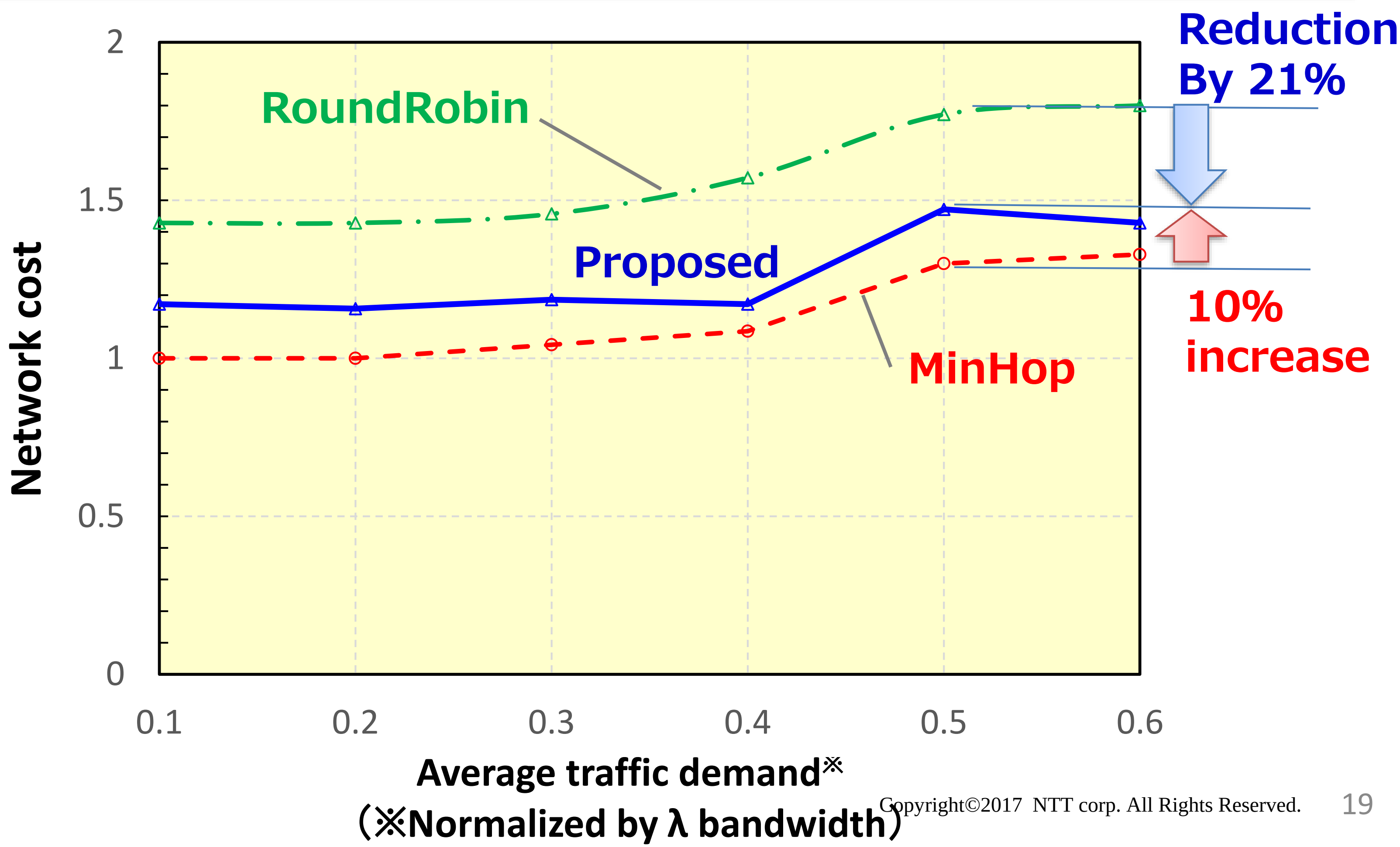
Result①: Design of parameter α

- To configure parameter α around 0〜1, we can efficiently disperse server load while avoiding increase in network cost.



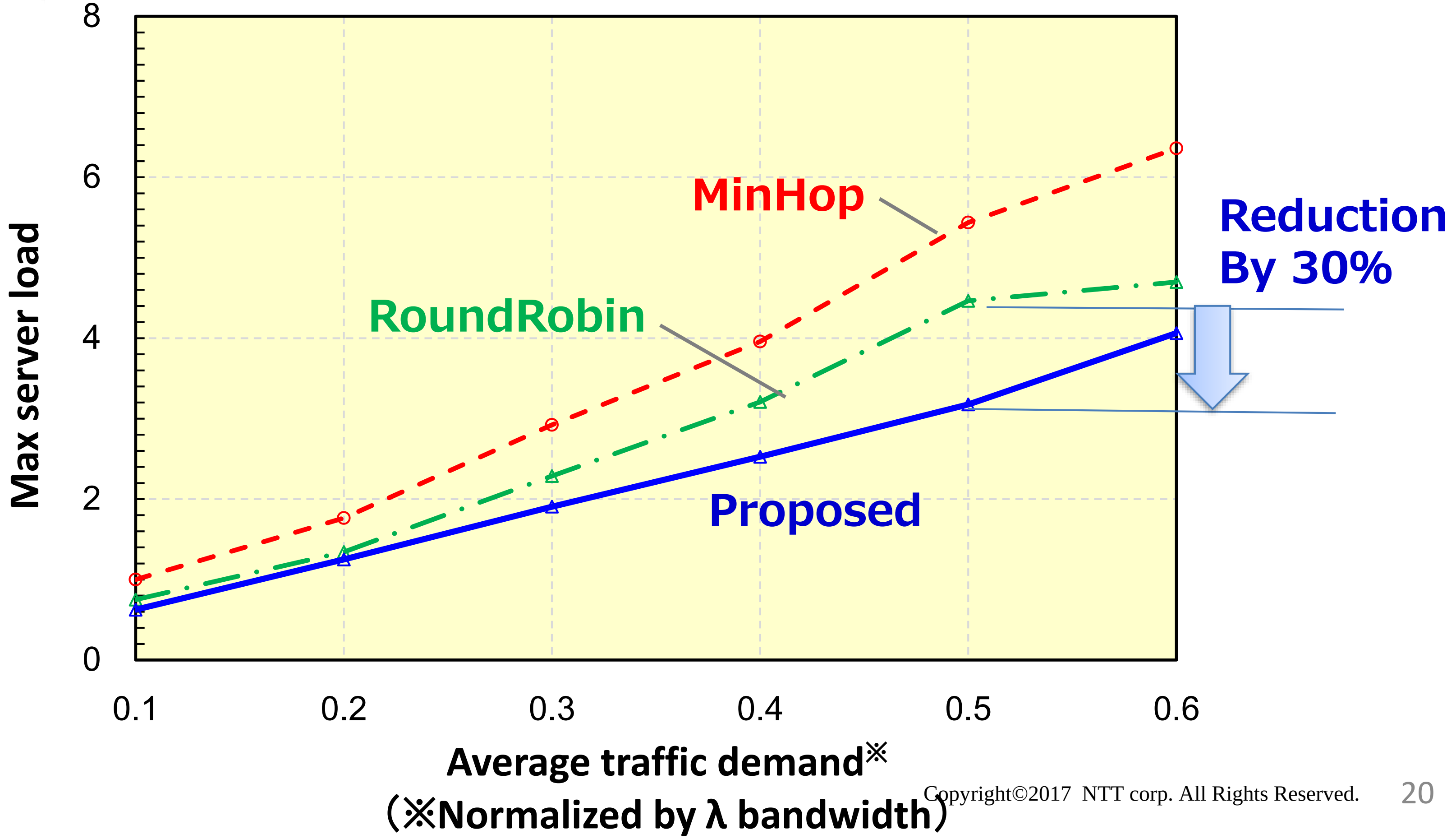
Result ②-1: Effectiveness

- Compare network cost for various traffic demand
- Proposed method reduced by up to 21%



Result ②-2 Effectiveness

- Compare max server load for various traffic demand
- Proposed method reduced by up to 30%



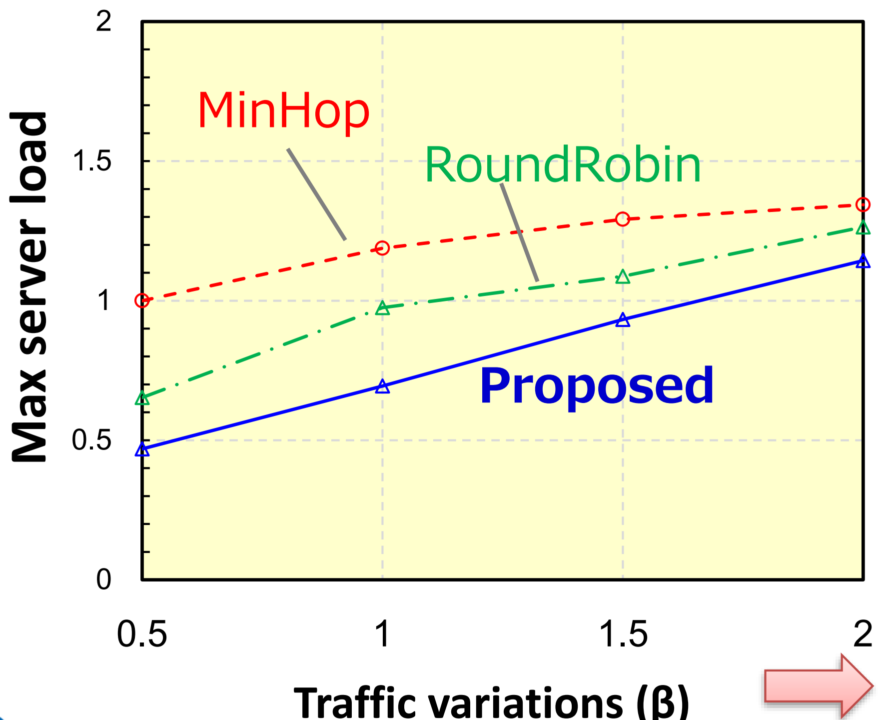
Result ③ Robustness

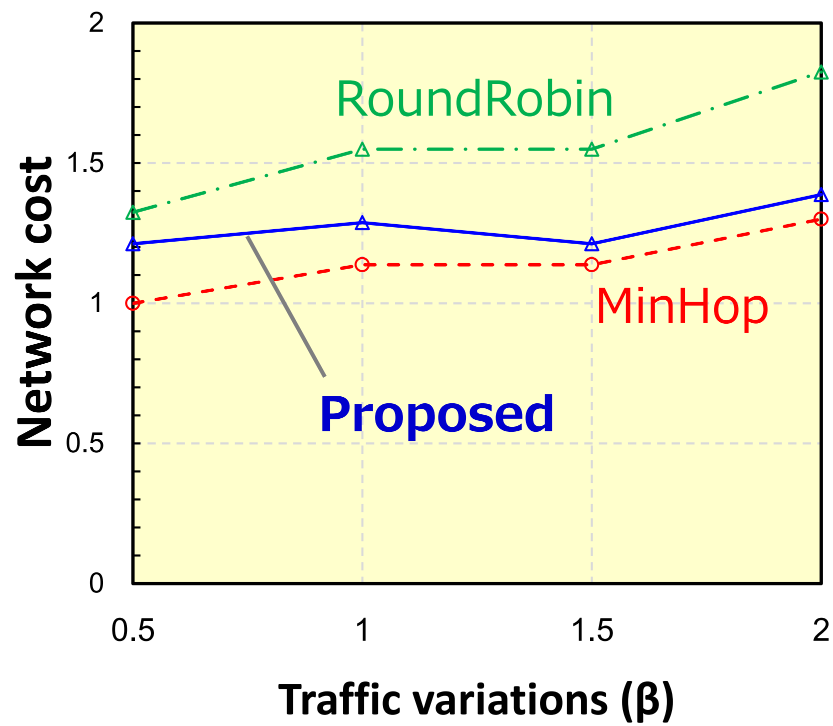
- Evaluate robustness for various traffic variations β

  Zipf distribution $T(x)=b*x^{-\beta}$

- Proposed method ensures robustness against traffic variations

Traffic=50





Sharp fluctuations

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Conclusions

- We studied the optimal design of optical aggregation networks with carrier edge function virtualization.
  - NFV improves efficiency of server resources for carrier edge functions.
  - Consider joint optimization problem that minimizes network cost and maximum server load.
  - Formulate the problem as mixed integer linear programming.
- We quantitatively evaluated effectiveness of the optimal aggregation network design with VNF placement.
  - It reduced the maximum server load and network cost by up to 30% and 21%, respectively.
  - Can improve resource efficiency and robustness to unpredictable demand changes.

Thank you
for your kind attention.