

Enhancing BoD Services based on Virtual Network Topology Control

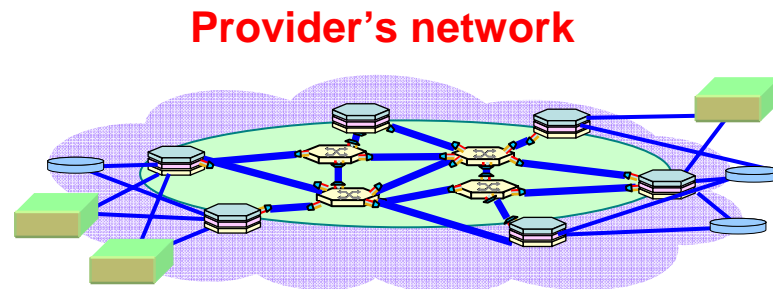
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Today's BoD service application scenario

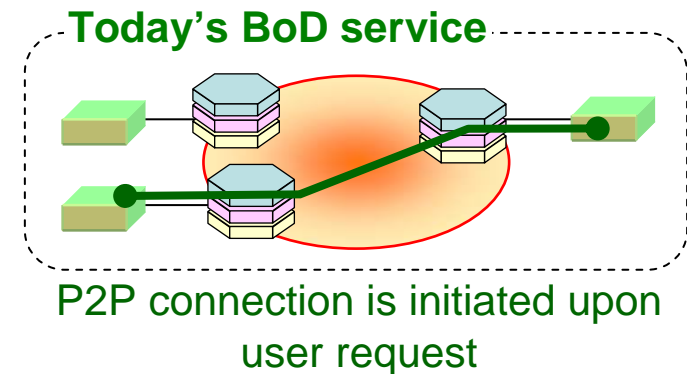
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- **Today's BoD service**

- A network provider offers high-capacity bandwidth to its customers
- Basically, the connectivity is limited to Point-to-Point.
- Customers often construct a part of their own network by combining multiple point-to-point connections.



Physical network configuration

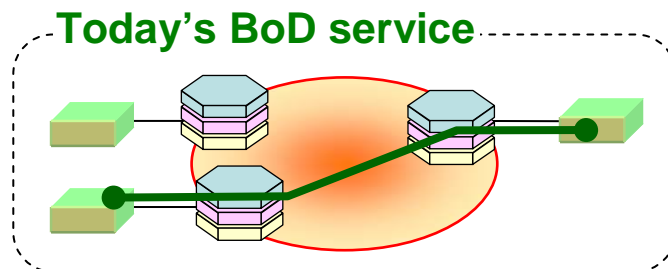


Today's BoD service application scenario *cont'd*

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- **Outline of our proposal**

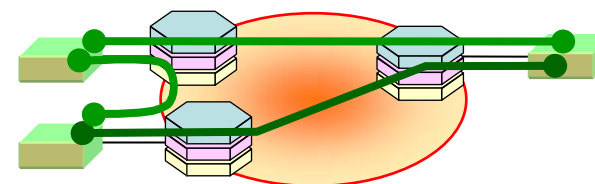
- The price is basically determined by service parameters (e.g., a holding time, bandwidth, etc.)
- Customers wish to minimize the total cost while maintaining adequate service quality.
- We consider a new service that offers a minimum-cost network configuration in combination with multiple point-to-point connections.



- Point-to-point connection

- Fixed bandwidth

Our proposal (VNT service)



- Multi-point connection

- Flexible bandwidth

Outline

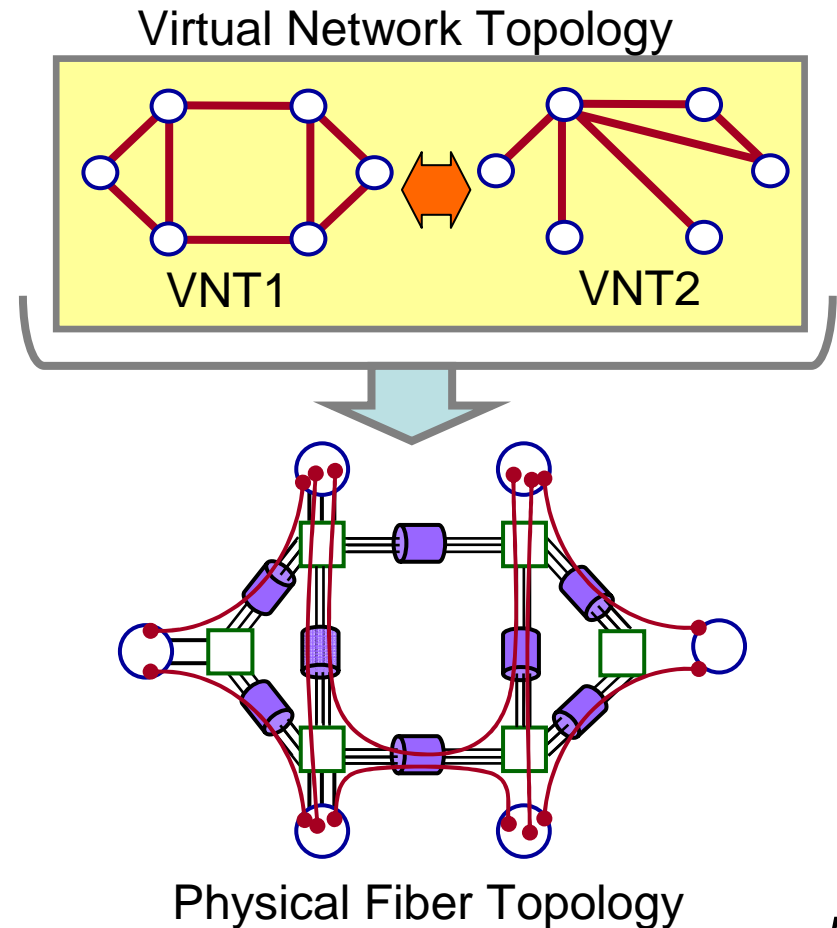
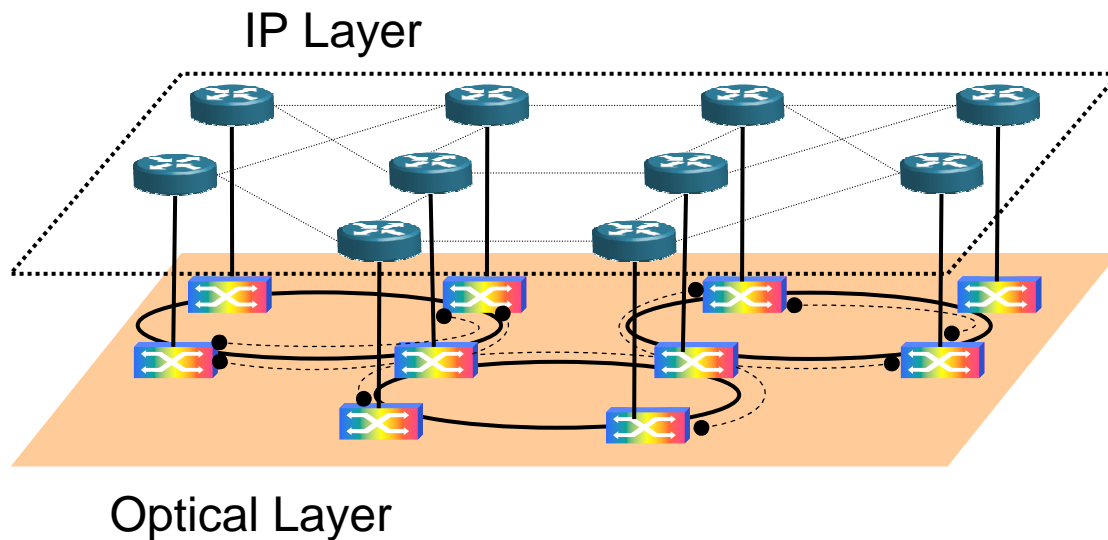
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1. VNT service
2. Technologies for VNT Services
3. Pricing mechanism
4. Numerical Example
5. Concluding Remarks

Virtual Network Topology (VNT)

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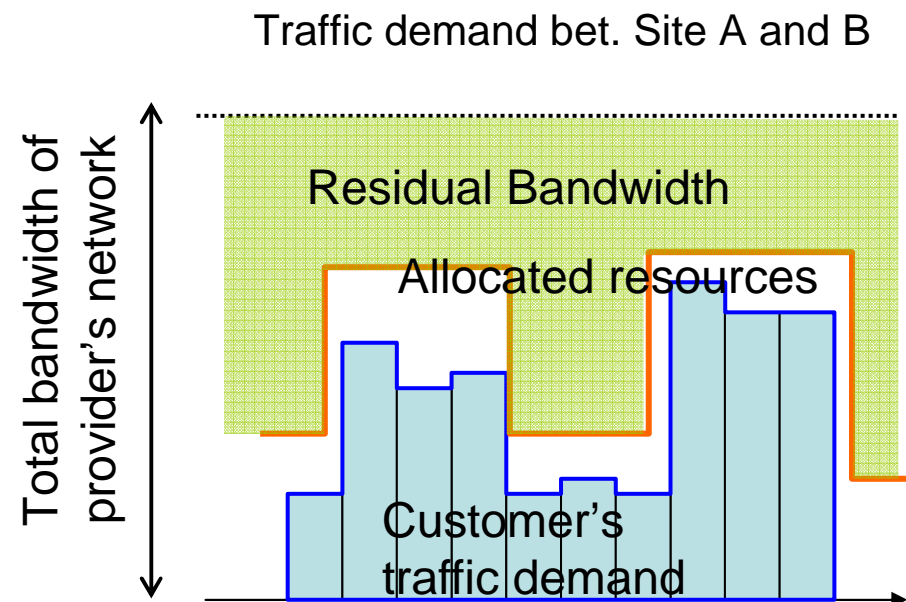
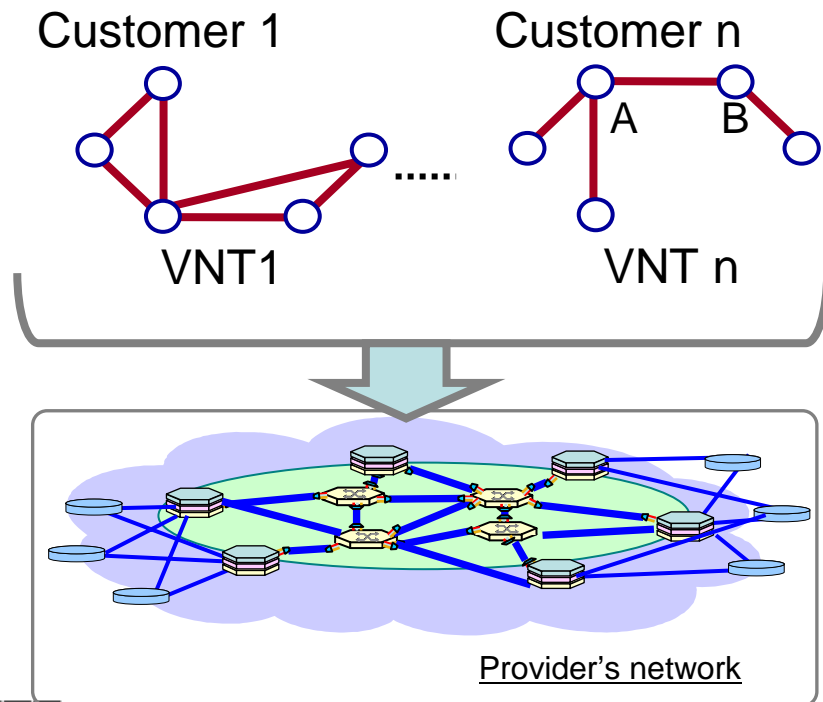
- The network topology formed by optical paths and advertised to the higher layer is called VNT.
- VNT is re-configured by optical paths setup/teardown.



Our proposal: VNT service

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- A service provider network provides continuous connections among multiple customer sites.
 - A set of connections corresponds to a VNT
 - Provider accommodates multiple customers (i.e., VNTs)
- Bandwidth of each pipe connecting a pair of customer edges is automatically adjusted in accordance with traffic-demand changes



Our proposal: VNT service *cont'd*

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- **Merits**

- Customers: improves flexibility regarding bandwidth and reduces OPEX and CAPEX
- Providers: Improves efficiency of resource utilization

	Conventional BoD Service	VNT Service
Connectivity	Point-to-Point	Muti-point
UNI (Data plane)	Any (L1/L2/L3)	Packet or Frame-based (L2/L3)
Connection initiation /release	Triggered by customer request	Continuously established
Allocated bandwidth	Manually specified upon connection request	Automatically adjusted based on actual demand by service provider
Operation cost for customer network	Estimating traffic demand and/or holding time is very complicated	No additional task is required for traffic demand variation

Technologies for VNT service

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- **Challenges: Providers wishes to minimize network cost.**
 - How to accommodate efficiently multiple customers traffic on the provider's network?
 - How to adjust network topology and bandwidth in response to time-varying traffic demand?
- **Technologies:**
 - **Multilayer Traffic Engineering (TE)** technology optimizes network resource considering all layer information for dynamically changing traffic.

Customer 1
Traffic demand

$$\begin{pmatrix} r_{1,1} & r_{1,2} & \cdots & r_{1,n} \\ r_{2,1} & r_{2,2} & \cdots & r_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n,1} & r_{n,2} & \cdots & r_{n,n} \end{pmatrix}$$

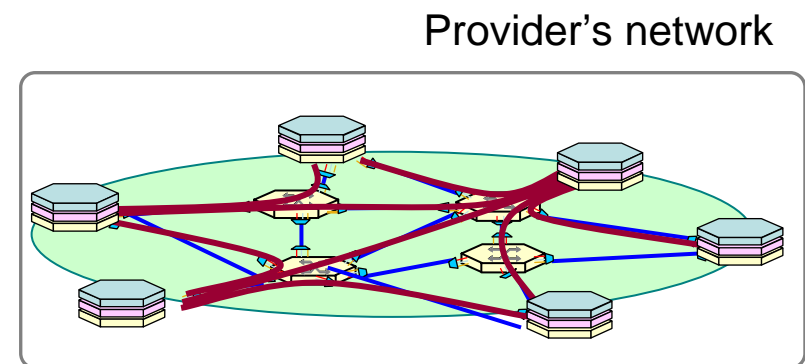
Input

Customer's traffic demand

.....

Customer n
Traffic demand

$$\begin{pmatrix} r_{1,1} & r_{1,2} & \cdots & r_{1,n} \\ r_{2,1} & r_{2,2} & \cdots & r_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n,1} & r_{n,2} & \cdots & r_{n,n} \end{pmatrix}$$



Output

Optimal VNT (network configuration)

Multilayer TE and IP optical TE server

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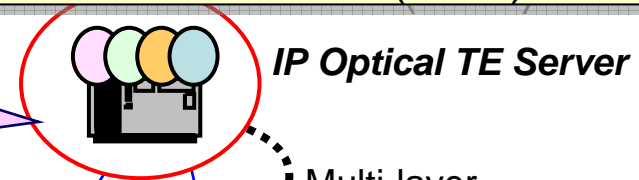
- **Multilayer TE**

- Optimizing network resource utilization considering all layers, rather than each layer independently.
- Optimization is realized by reconfiguring VNT

- **IP optical TE server**

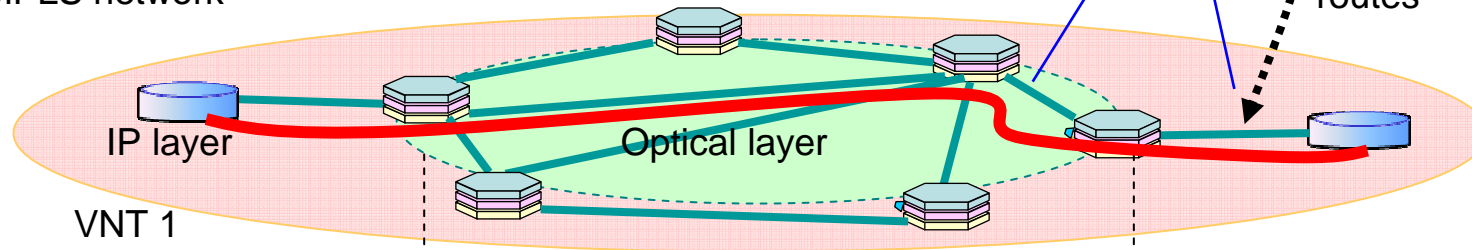
- Provides advanced path computation function and VNT control
- Interface bet. Server and network is based on PCE architecture (IETF)

Carriers' policy implemented
(Multi-layer, quality of service, reliability, etc.)
Policies can be customized.



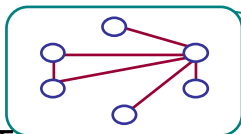
IP Optical TE Server

IP/MPLS network

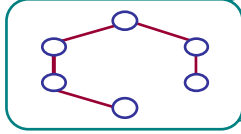


Multi-layer routes

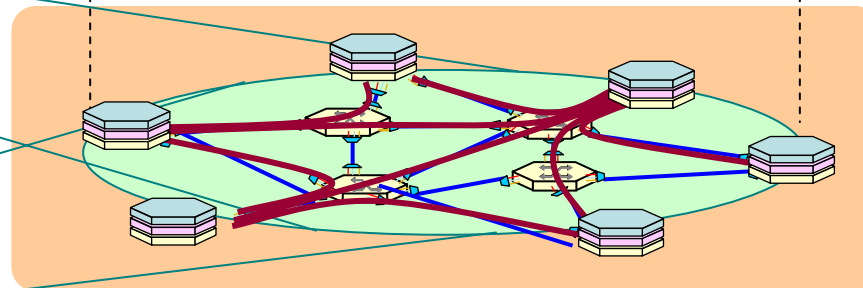
VNT 1



VNT reconfiguration



VNT 2



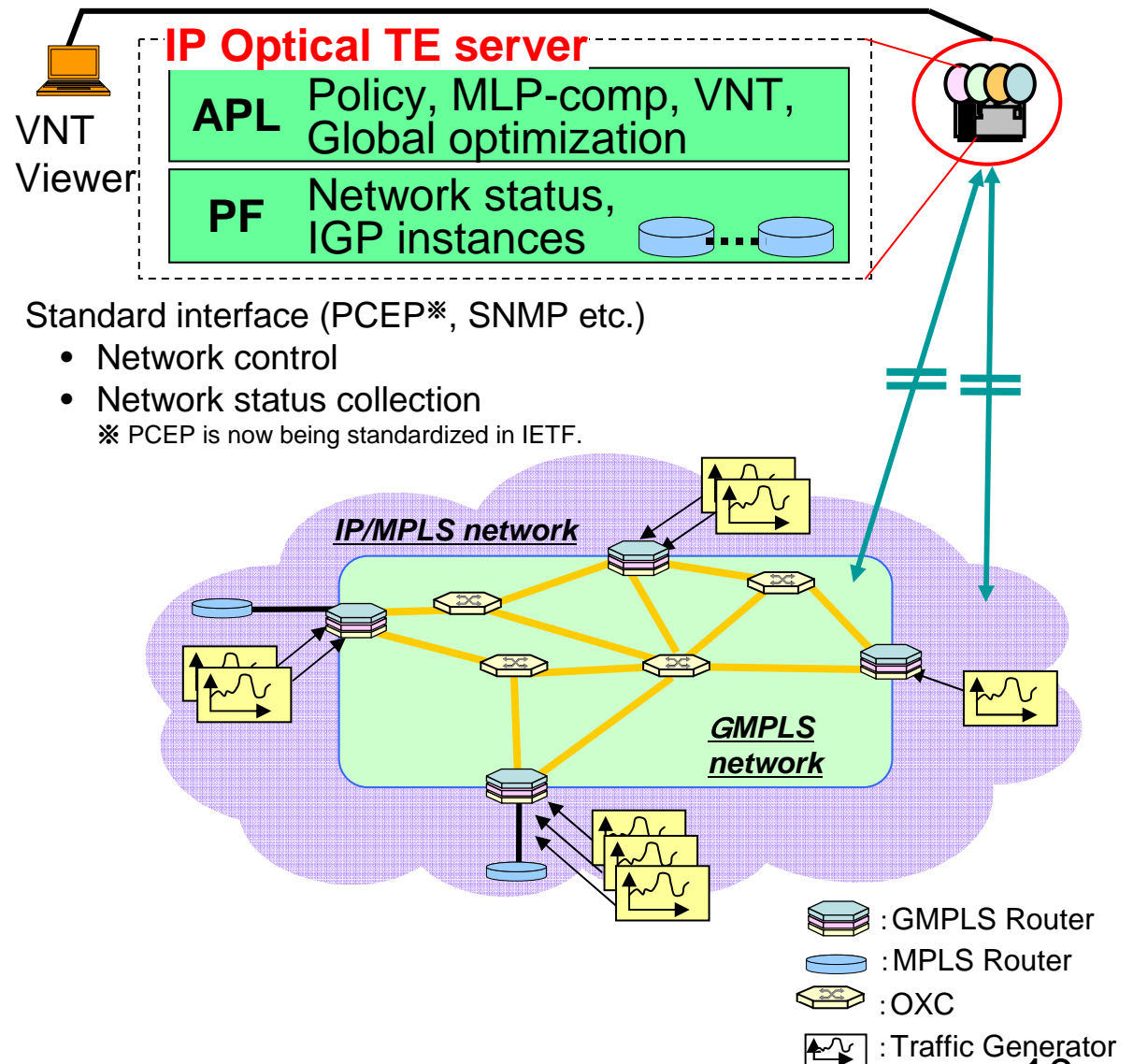
Optical network

VNT: Virtual Network Topology

Experimental Demonstration

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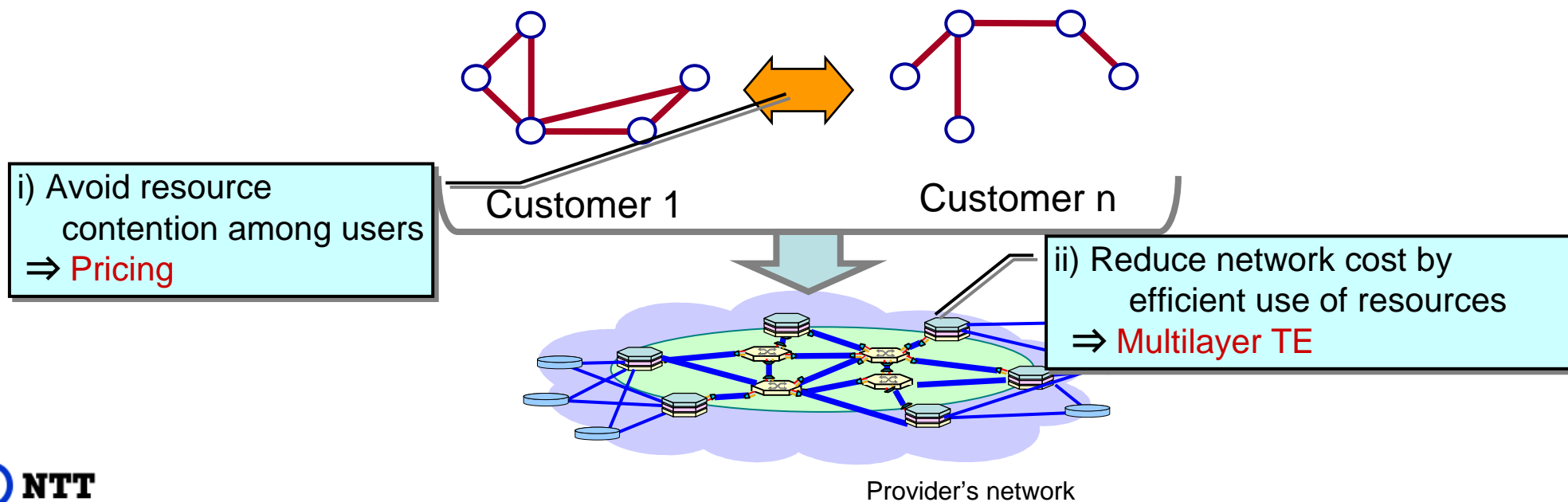
- Multilayer traffic engineering was successfully demonstrated using our newly developed IP optical Traffic Engineering (TE) Server.
 - Computes path routers across different layers and controls them upon request
 - Dynamically reconfigures an IP network topology in response to traffic demand fluctuations and network failures



Challenges for VNT service

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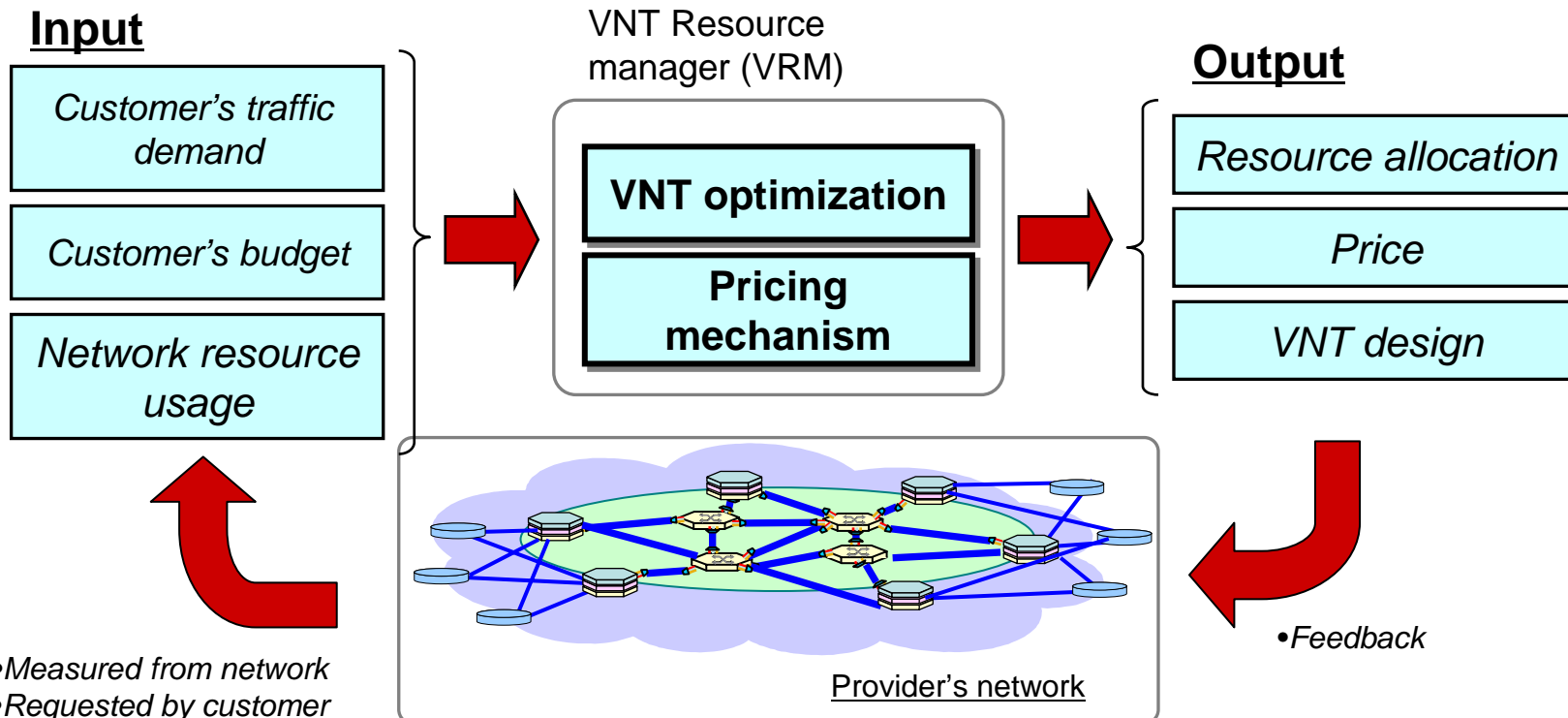
- Goal (Economics aspect)
 - We want to maximize the utility of users; at the same time, maximize the profit of the service providers.
- Possible problems
 - i) Each user share the same objective. Resource contention will occur.
 - ii) Network cost increases if resources are provisioned to cover the peak demand.
- Our approach
 - We introduce i) **pricing mechanism** and ii) multilayer TE technologies.



Pricing mechanism: Overview

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- Network resources in a provider's network for the VNT service are shared by multiple VNTs
- Some mechanism is required for avoiding the exhaustion or contention of network resources.
 - VNT optimization function computes the optimal VNT for a given demand
 - Pricing mechanism determines an adequate price and resource allocation considering residual network resources and customer's benefit.



Pricing mechanism

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- **Objective**

- Maximize the sum of user utility and profit of provider

Maximize

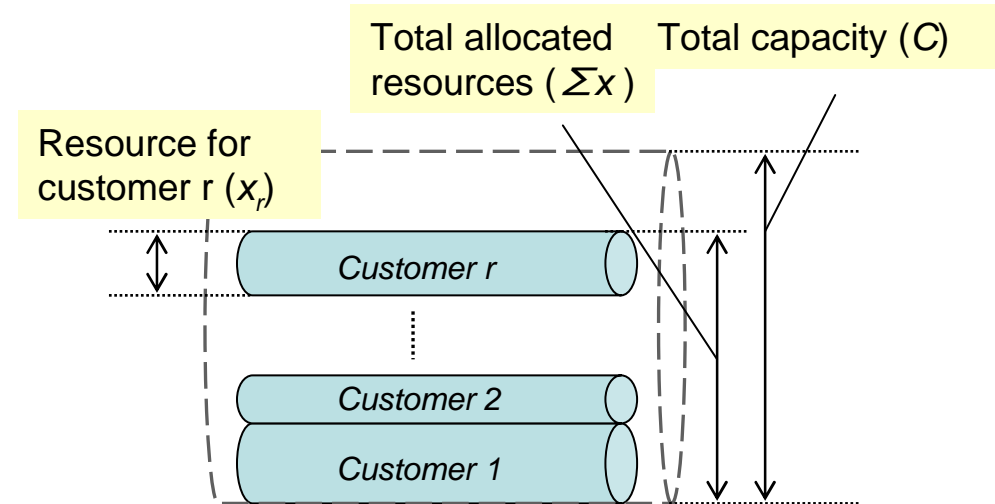
$$\left\{ \sum_{r \in R} (U_r(x_r) - C_r(x_r)) \right\} + \alpha \cdot \left\{ \sum_{r \in R} (C_r(x_r) - C_p(x_r)) \right\}$$

- **Subject to**

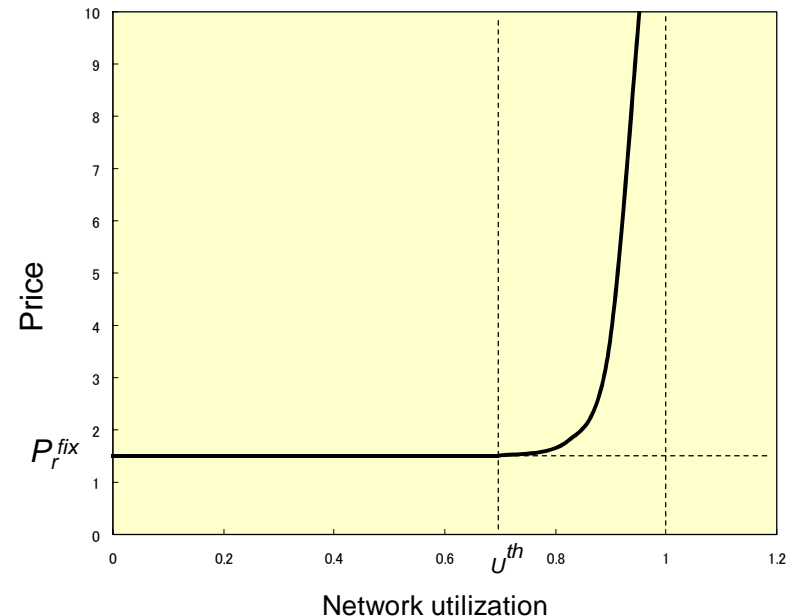
- Capacity constraint
- Budget constraint
- Service quality constraint

- **Qualitative characteristic**

- Avoid resource contention among customers
- obtain the optimal pricing and network resources allocated to each customer



Pricing function

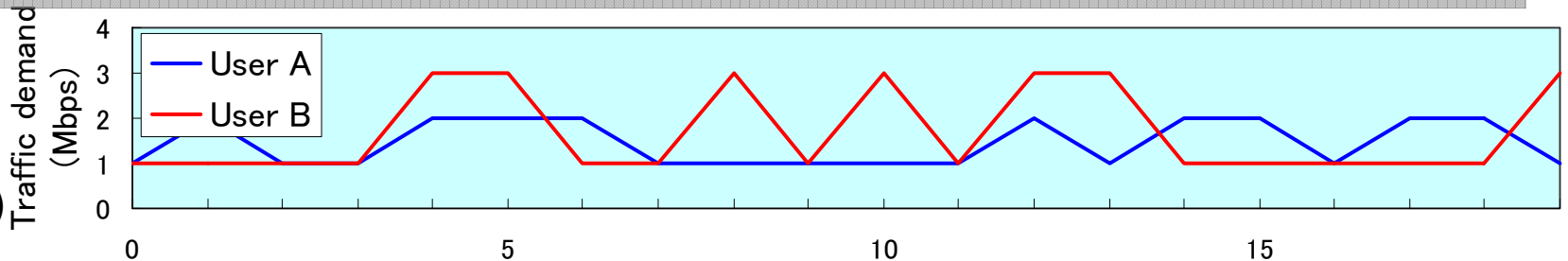


Numerical Example

- Aim of performance evaluation
 - Clarify the impact of traffic demand conditions on the effectiveness
 - We measure the effectiveness from the viewpoint of users
- Simulation conditions
 - Network model; One-link network model, 2 users share the capacity of 5 Mbps
 - Cost: 1 Mbps/hour – 10\$ (Basic tariff)
 - **Traffic model: i) Highly fluctuated demand, ii) Stable demand**
- Performance measure :Cost paid by each user
 - Fixed tariff: Each user pay the fee for the peak demand during the term
 - Proposed method: Each user pay according to the amount of usage.
 - ⇒ We add 50% extra fee in case the utilization is over 80%

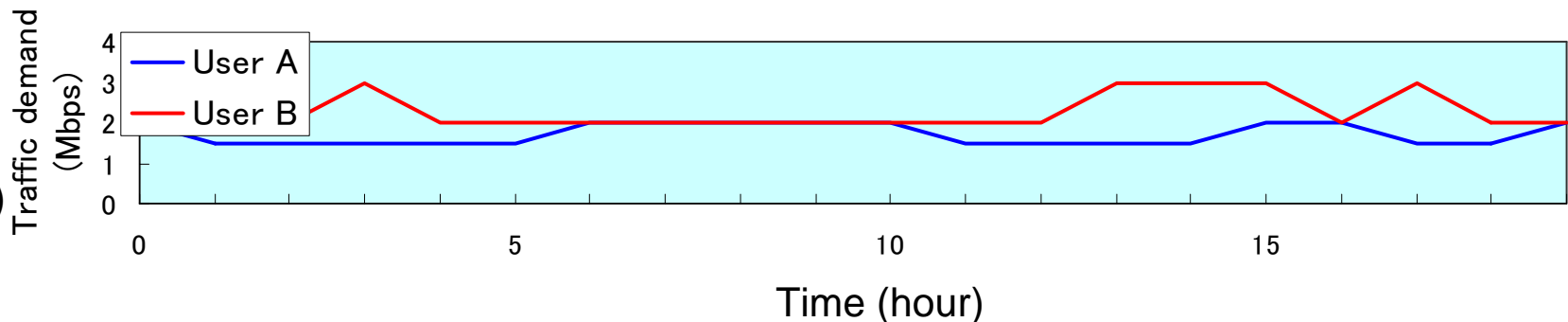
Case 1:

Highly fluctuated
(60% in average)



Case 2:

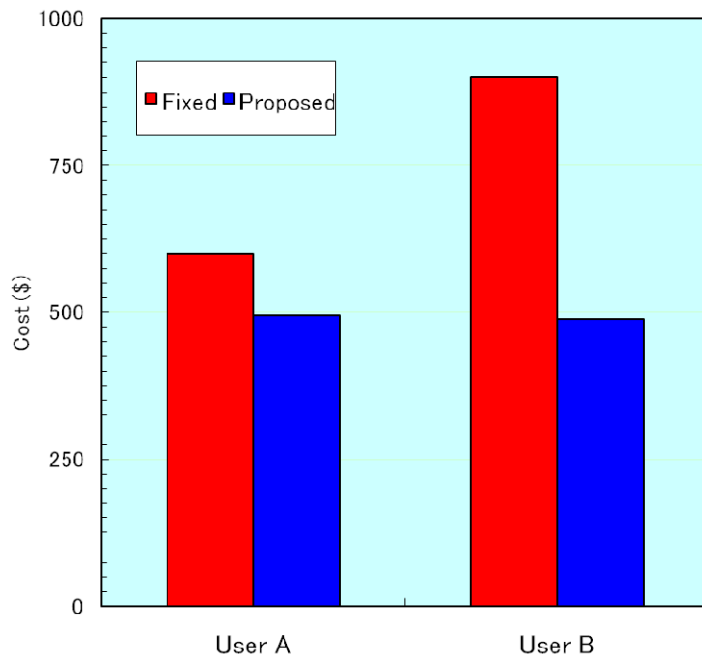
Stable
(80% in average)



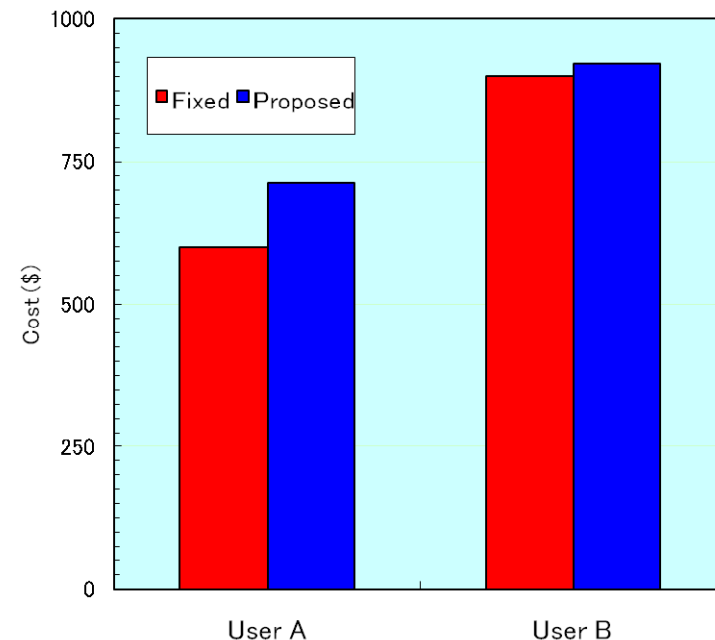
Simulation Results

- Proposed method is more effective for high fluctuated traffic conditions
 - In Case 1, total cost for users decreased by 35%
 - However, in Case 2, the cost increased slightly by 8%
 - Among users, User B (demand is more variable) is more advantageous
- For providers, the revenue decreases by 35%.
 - However, 40% of network resources remained unallocated in average.

Case 1: Highly fluctuated demand



Case 2: Stable demand



Observation

- **Findings**

- If the traffic demand is fluctuated, our mechanism is very effective for users.
 - In some case, user can reduce the cost by 35%.
- This means the decrease in provider's revenues. We need to investigate the merit of service provider

- **Discussion: How to increase the total profit for providers?**

- Improving the utility of users can leads to increase in sales
- Utilize effectively residual bandwidth.
 - Introduce time-reservation-based BoD service. Allocate residual bandwidth.
- Multilayer TE technology reduces the network cost, which can cover the revenue decrease.
 - In our study, it can reduce network cost by 40% for fluctuated traffic conditions

Concluding Remarks

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- **Conclusion:**

- This paper presented multilayer IP optical TE technologies based on VNT control and proposed its application to BoD services.
- The VNT service can improve flexibility regarding bandwidth while reducing operation overhead and maintaining advantages of existing BoD services.
- We demonstrated the effectiveness of our proposal through numerical study.

- **Further study:**

- Investigate the merit of service provider (how to utilize effectively residual bandwidth)
- Extends a simulation model (simple one link model to multiple link model)
- More sophisticated VNT optimization algorithms