Paper Review: Spectrum Trading between Virtual Optical Networks Embedded in an Elastic Optical Network

S. Ding, X. Fu, B. Jiang, S. K. Bose, and G. Shen, "Spectrum Trading between Virtual Optical Networks Embedded in an Elastic Optical Network," in *Proc. Optical Fiber Communication Conference*, Mar. 2019.

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Outline

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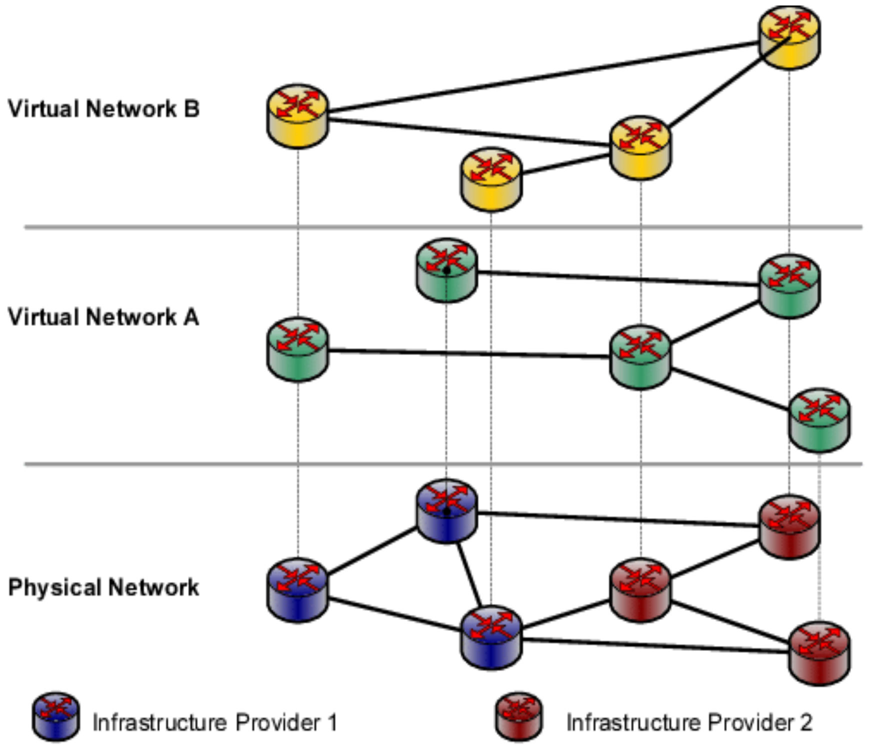
Motivation

- Virtual optical networks(VON) is embedded with fixed capacity in VON's contract period.
- Real time traffic fluctuations.
- Both large idle capacity and capacity shortage is observed on virtual links.
- Solution: Spectrum trading(ST).
- Capacity is traded based on current capacity needs and returned if situation reverses.

Spectrum Utilization Improved!



Spectrum trading between virtual optical networks

ST scheme

- Divides the lifecycle of VON into time slots.
- In each time slot, virtual links with idle capacity(frequency slot (FSs)) trade idle FSs with virtual links that are short of capacity.
- Virtual links have to share common physical link(s) to be able to trade.
- VON that provides capacity, gets a **positive credit** to the amount of capacity traded.
- **Negative credit** for the recipient VON.

Example of spectrum trading

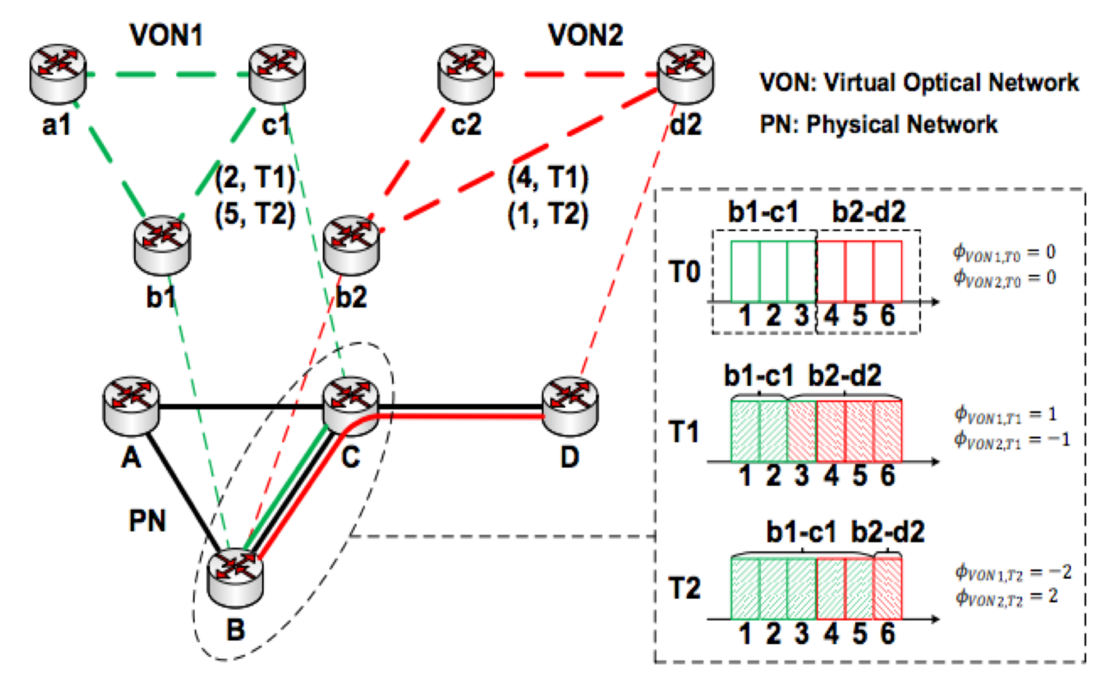


Fig. 1. An example of spectrum trading.

Common shared link is B-C.

At T0, b1-c1 and b2-d2 are assigned to 3 FSs.

At T1, b1-c1 needs 2 FSs & b2-d2 needs 4 FSs.
25% traffic block in b2-d2.

At T2, b1-c1 needs 5 FSs & b2-d2 needs 1 FS.
40% traffic block in b1-c1.

Spectrum utilization improved by,
(12-9)/12 = 25%.

Fairness in trading

- Cumulative credit parameter is calculated for each VON.
- If cumulative credit parameter<threshold(in time T), stop VON from borrowing any resources.
- This threshold is pre-decided.
- This avoids a selfish client situation which only uses other's resources, without sharing its own.

$$\gamma_{v,T} = \sum_{i=1...T} \phi_{v,i},$$

$$\gamma_{v,T} < \mu$$

Integer linear programming constraints

Objective function: Maximize the amount of traffic demand that can be supported by the VONs in different time slots.

Input:

Physical topology

Set of VONs

Each VON has predefined topology

$C(v, s, d, x, y)$: each virtual links of VONs are assigned to set of FSs

$R(v, s, d, t, Ft)$: bandwidth demand on each virtual link of a VON at different time slots

Integer linear programming constraints

Constraints:

(1) A virtual link uses its own FSs to carry its own traffic demand at the first place.

(2) A virtual link cannot use an FS if it is not owned by any VON.

(3) The number of FSs that a virtual link borrows should not exceed its need.

(4) The spectrum assigned for two virtual links should not overlap if their mapped physical routes share common link(s).

(5) A VON cannot borrow any FS from other VONs in subsequent time slots if its cumulative credit is negative and smaller than the threshold μ mentioned earlier.

Heuristic algorithm

Heuristic algorithm for Spectrum Trading
Step 1: Use the capacity assigned to each virtual link of a VON to carry its traffic demand; **Step 2:** Sort all the virtual links in a descending order based on the amounts of traffic demands that cannot be accommodated using their own capacities; the ordered list is denoted as *L*; **Step 3:** Get the first virtual link *l* from *L*; if the cumulative credit of its corresponding VON is not smaller than a preset negative threshold , go to Step 4; otherwise, go to Step 5; **Step 4:** Borrow unused capacity on other virtual links to accommodate the unserved traffic demand of virtual link *l* at the best effort through spectrum trading; update the cumulative credits for all the related VONs in the trading process; **Step 5:** If not all the links in *L* have been considered, then get the next virtual link *l* from *L*, go back to Step 4; otherwise, go to Step 6; **Step 6:** Stop the traffic demand provisioning process and output the results.

Simulation setup

- 6-node, 8-link (n6s8) network and 15-node, 21-link NSFNET network.
- 8 VONs with same lifecycles, uniformly divided into 4 time slots.
- Virtual nodes and virtual links belonging are randomly generated within the ranges of [N/2, N] and [L/2, L], where N and L : numbers of physical network nodes and links, respectively.
- Traffic demand matrix between node pairs, in which each node pair has the same average traffic demand with an intensity selected from the set $X \in \{40, 60, \cdots, 140\}$ Gb/s.
- The cumulative credit threshold μ = -10.

Illustrative results

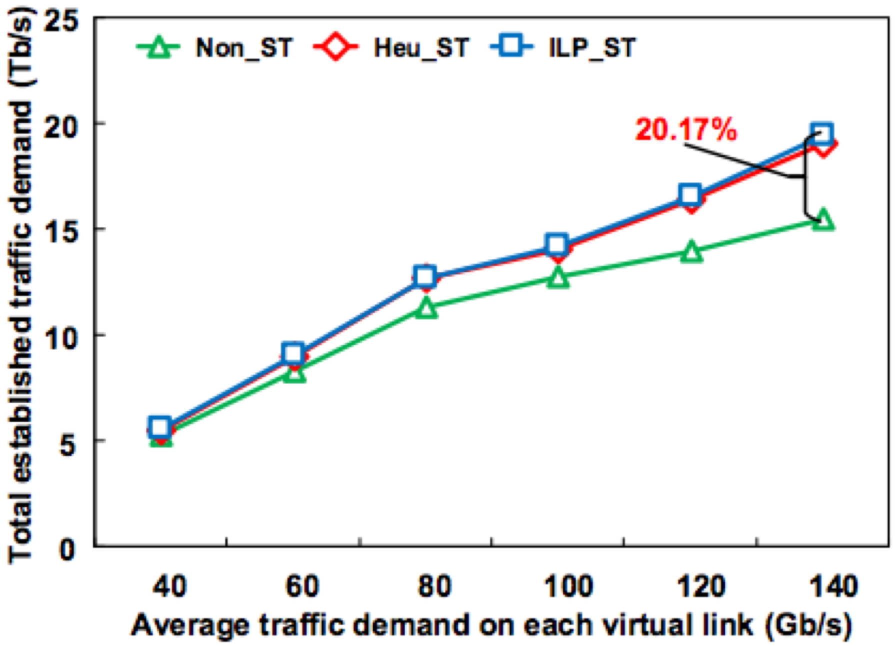


Fig. 3. Results of the n6s8 network.

Non_ST: Without ST
Heu_ST: Heuristic of ST
ILP_ST: ILP of ST

- Larger average traffic demand corresponds to larger fluctuation of actual traffic demand. So ST gets opportunity improve capacity utilization by trading spectrum between VONs.
- Heuristic is very close to ILP.

Compares the amount of overall traffic demand that is actually carried by the VONs under different average traffic demands in the n6s8 network,

Illustrative results

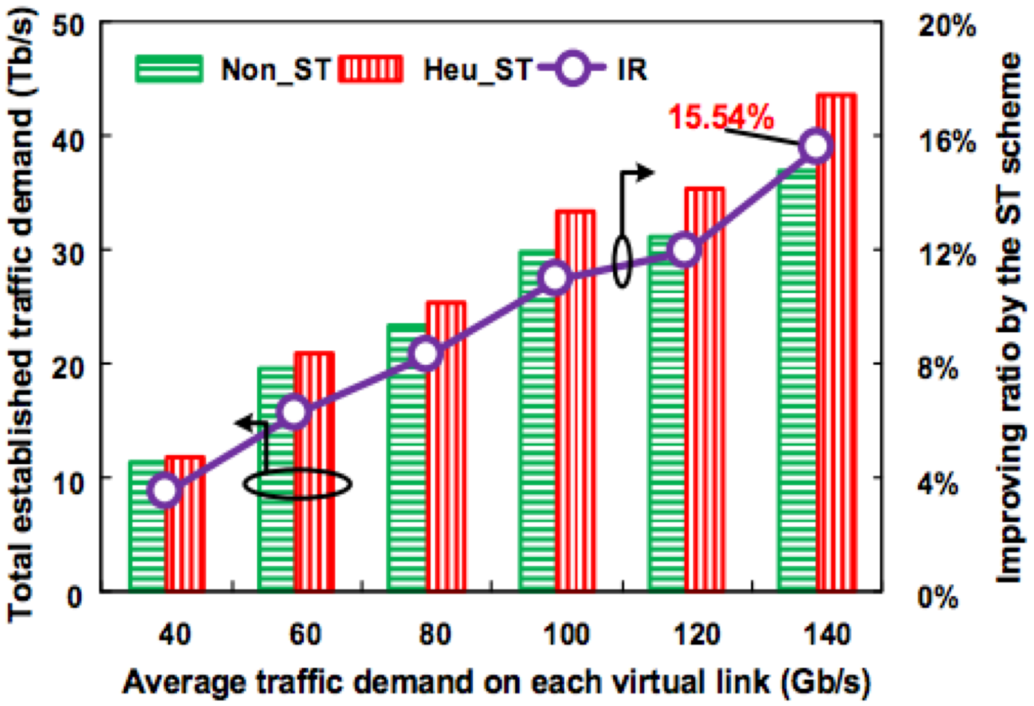


Fig. 4. Results of the NSFNET network.

Non_ST: without ST
Heu_ST: Heuristic of ST
IR: Improvement ratio

The curve of "IR" shows the improvement ratio by the ST scheme over without ST. ST scheme performs better with an increasing average traffic demand, by more than 15%.

Illustrative results

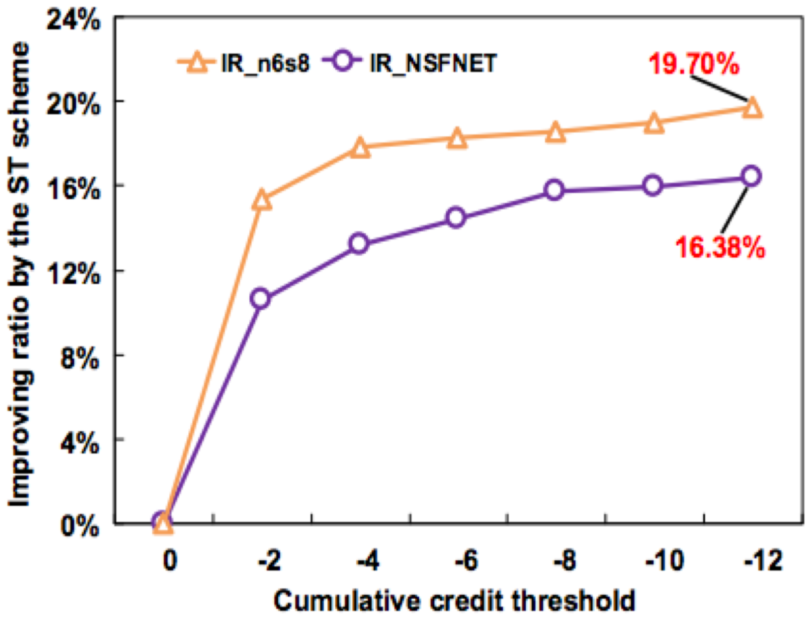


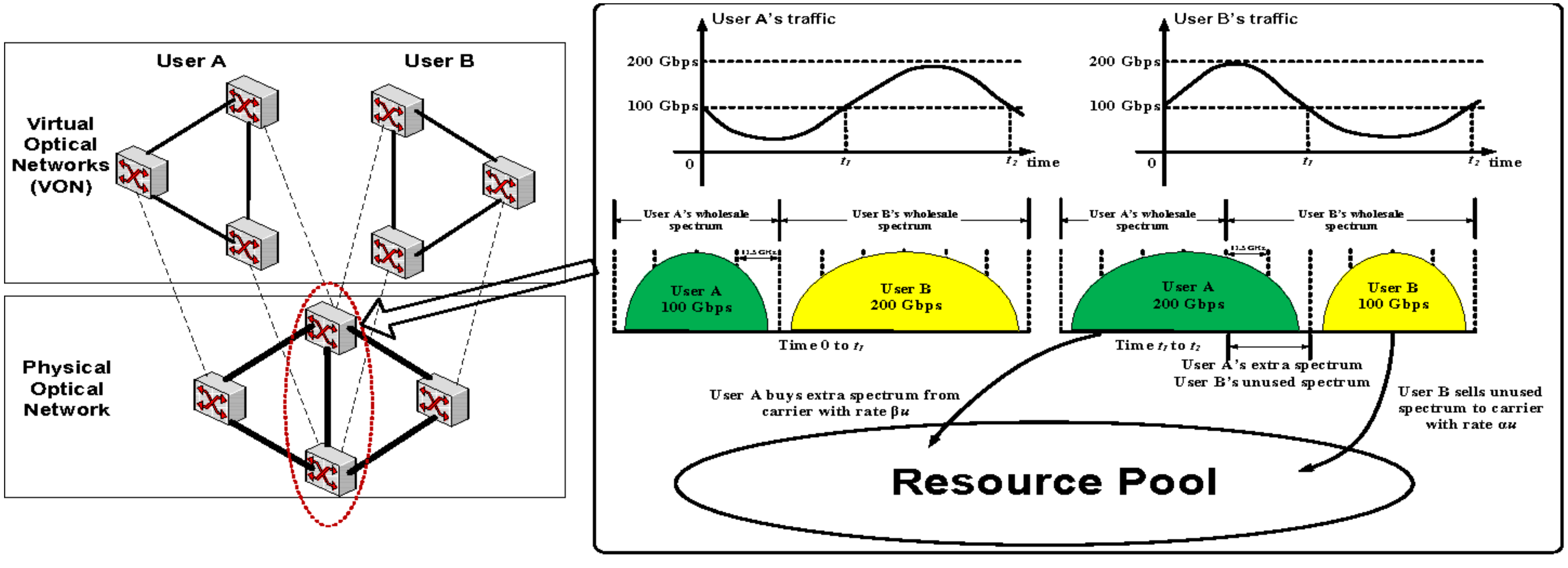
Fig. 5. Impact of cumulative credit threshold (X=140 Gb/s)

With increase of threshold, the improvement ratio increases for both networks. However, this improvement saturates for a large cumulative credit threshold, implying that a small credit threshold may be sufficient to give good performance and prevent selfishness.

Conclusion

- Proposed scheme that allows VONs to trade their spectrum resources according to their actual traffic demands in different time slots.
- Although this study uses the term ‘trading’. The trading is not immediate.
- No explanation of how to choose the cumulative credit threshold.
- What happens in case the traded capacity does not match with the requirements.

Dynamic resource pooling and trading mechanism



W. Xie, J. Zhu, C. Huang, M. Luo, and W. Chou, "Dynamic resource pooling and trading mechanism in flexible-grid optical network virtualization," in *Proc*. *Cloud Networking*, pp. 167-172, Oct. 2014.