Routing, Fiber, Band, and Spectrum Assignment (RFBSA) for Multi-granular Elastic Optical Networks

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Background

Elastic Optical Networks (EON):
- High Spectral Efficiency
- Flexible Rate
- Contiguous frequency slot band

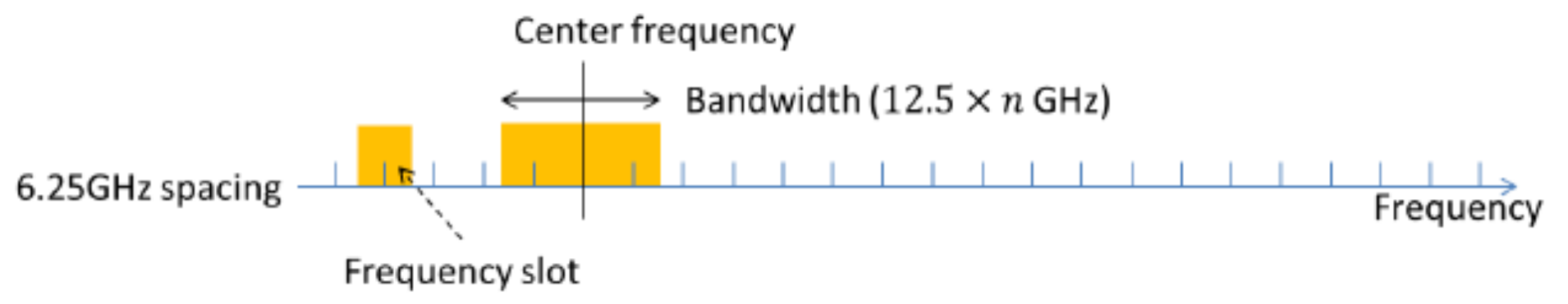

Figure 1: Frequency assignment to optical paths in flex-grid networks

Motivation

Optical Cross-Connect (OXC):
- Switching nodes
- Continuous traffic growth
- Multiple-fiber links are expected
- Large-scale OXC

- WSS typically come in 1x4, 1x9, or 1x20 configurations
- Larger WSSs built by cascading – increased losses, narrower passband

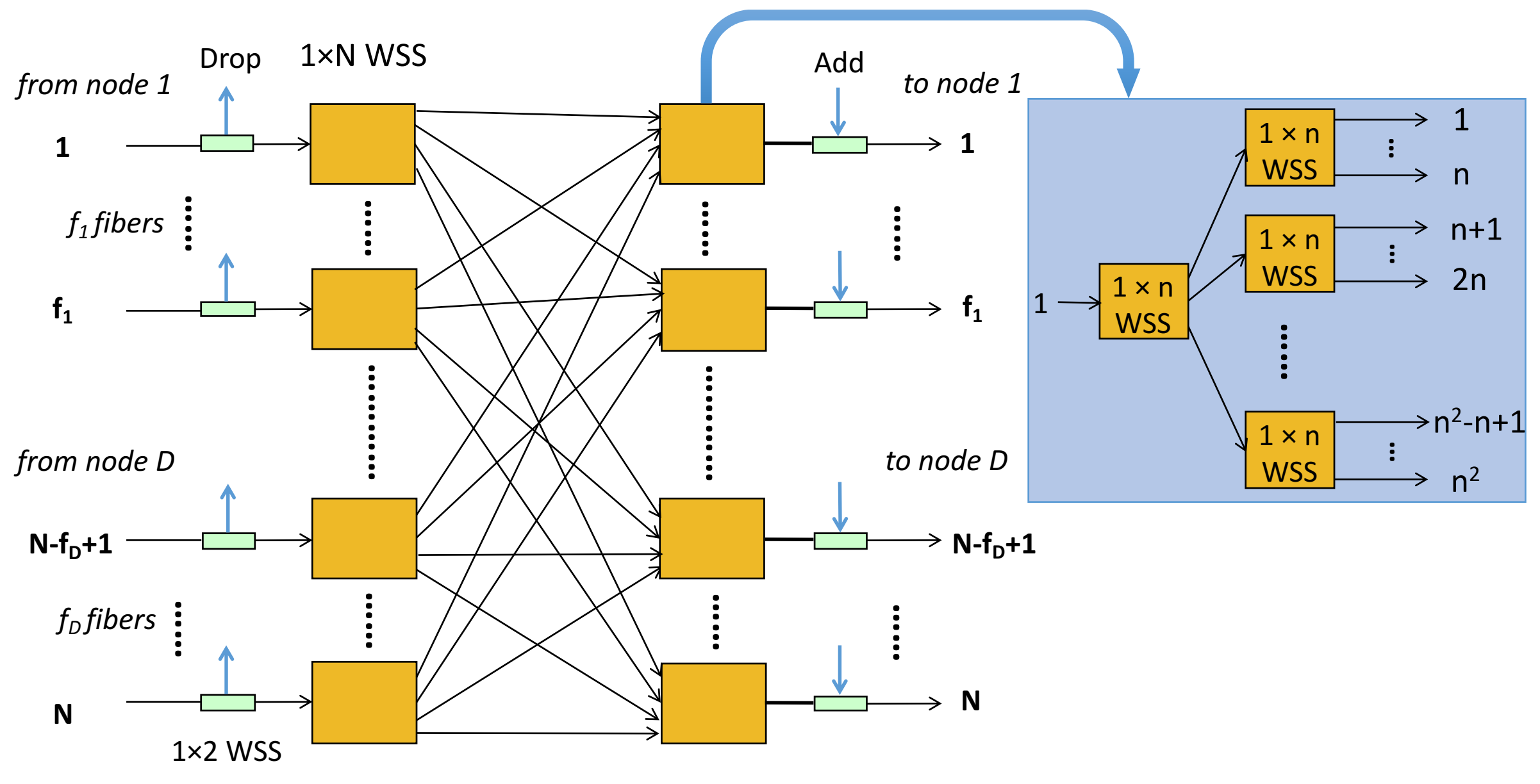

Figure 2: Conventional node architecture.

- No routing restriction: any wavelength from any input fiber can be routed to any output link/fiber as long as there are no wavelength collisions
- A 4x4 OXC requires 8 1x4 WSSs
- A 16x16 OXC requires 32 1x16 WSSs (or 160 1x4 WSSs)

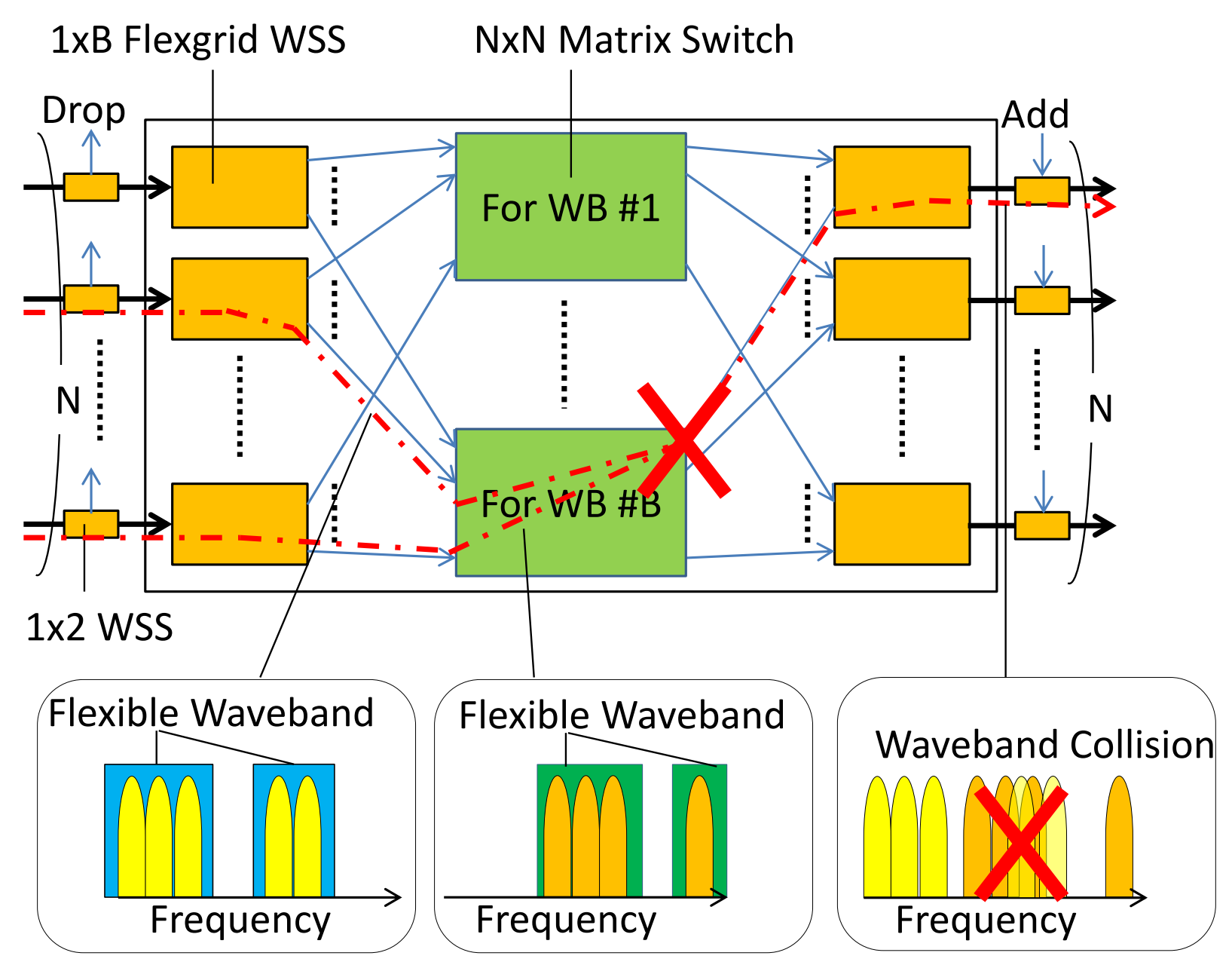

Figure 3: Flexible waveband node architecture.

- **Cost effective if B is small enough.**
- Routing restriction: for each input fiber, # of selectable output fibers is up to B
- Due to the flexibility in band allocation, we must always care about the overlapping of wavebands

Objective

- Given a set of traffic requests, assign a path which consists of links and fibers, and frequency slots to each request.
- The assignment should meet the wavebanding, spectrum nonoverlapping, spectrum continuity and spectrum contiguity constraints.
- **RFBSA:** to minimize the maximum spectral usage (MSU).

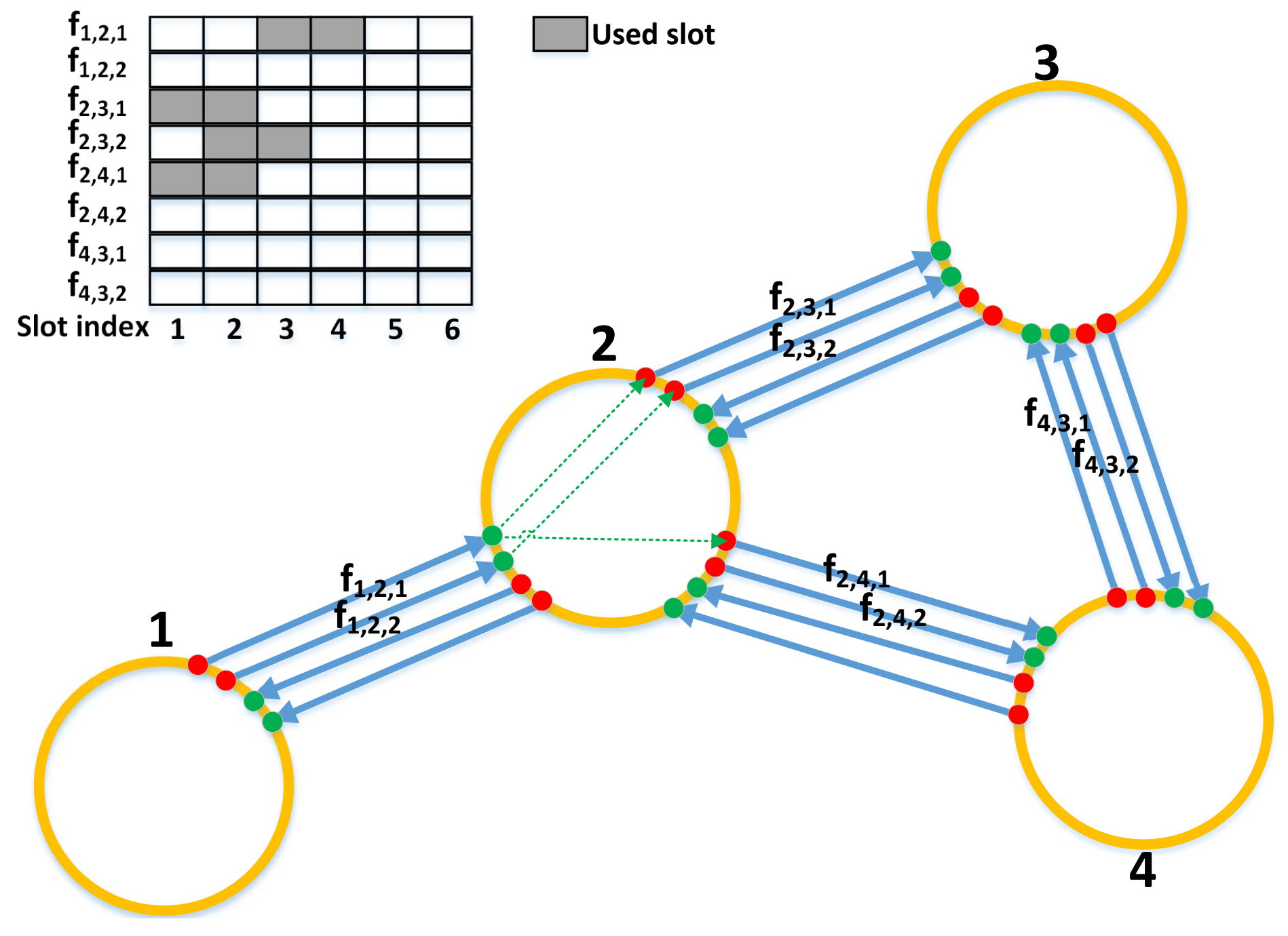

Figure 4: Illustrative example.

Methods

- Auxiliary layered-graph framework

  ✓ nodes in the auxiliary graph denote all input and output fibers;
  ✓ links from nodes denoting input fibers to nodes denoting output fibers represent the switching inside the corresponding physical node; link costs are related to the wavebanding status;
  ✓ links from nodes denoting output fibers to nodes denoting input fibers represent the physical link connection; link costs are related to the spectrum usage;

  ✓ update waveband costs for each request; denote $C_{v,f_{in},f_{out}}$ as the waveband cost from f_{in} to f_{out} in node v :

$$C_{v,f_{in},f_{out}} = \begin{cases} 0, & \text{if the waveband is established} \\ \alpha \cdot b, & \text{if } b < B \\ \infty, & \text{otherwise.} \end{cases}$$

  ✓ each auxiliary graph involves one outgoing fiber κ from source of request;
  ✓ layered graphs correspond to available slot sets on κ; update spectrum costs; denote $C_{r,\kappa,\widetilde{ss},f}$ as the spectrum cost of slot set $\widetilde{ss}$ on fiber f in AGκ for request r :

$$C_{r,\kappa,\widetilde{ss},f} = \begin{cases} 1, & \text{if } SI + w_r - 1 \leq f_{sl} \\ \infty, & \text{if } \widetilde{ss} \text{ is not available on } f \\ SI + w_r - 1, & \text{otherwise.} \end{cases}$$

  ✓ find the shortest paths (from the node denoting κ to nodes denoting input fibers of the request destination) in the auxiliary graphs and choose the minimum cost.

- This framework can allocate route and spectrum jointly.
- The pluggable cost functions can be modified regarding to different objectives.

Results

The results from our proposed algorithm are compared with those from a commonly-used baseline algorithm for both FLEX and CONV architectures.

- SPFF
- SPFBSA
- RSBFA

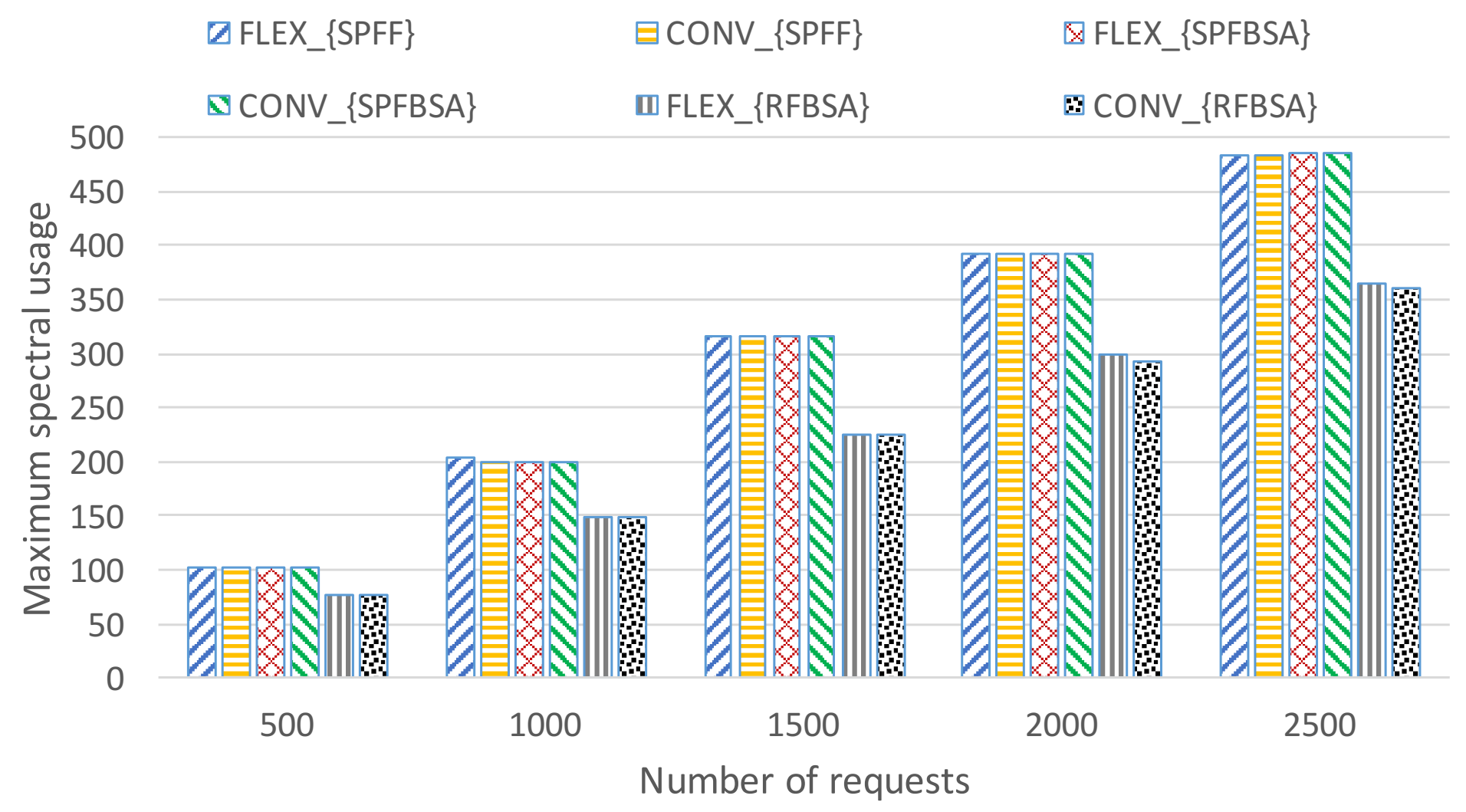

Figure 5: Performance comparison results for NSF network (F=2).

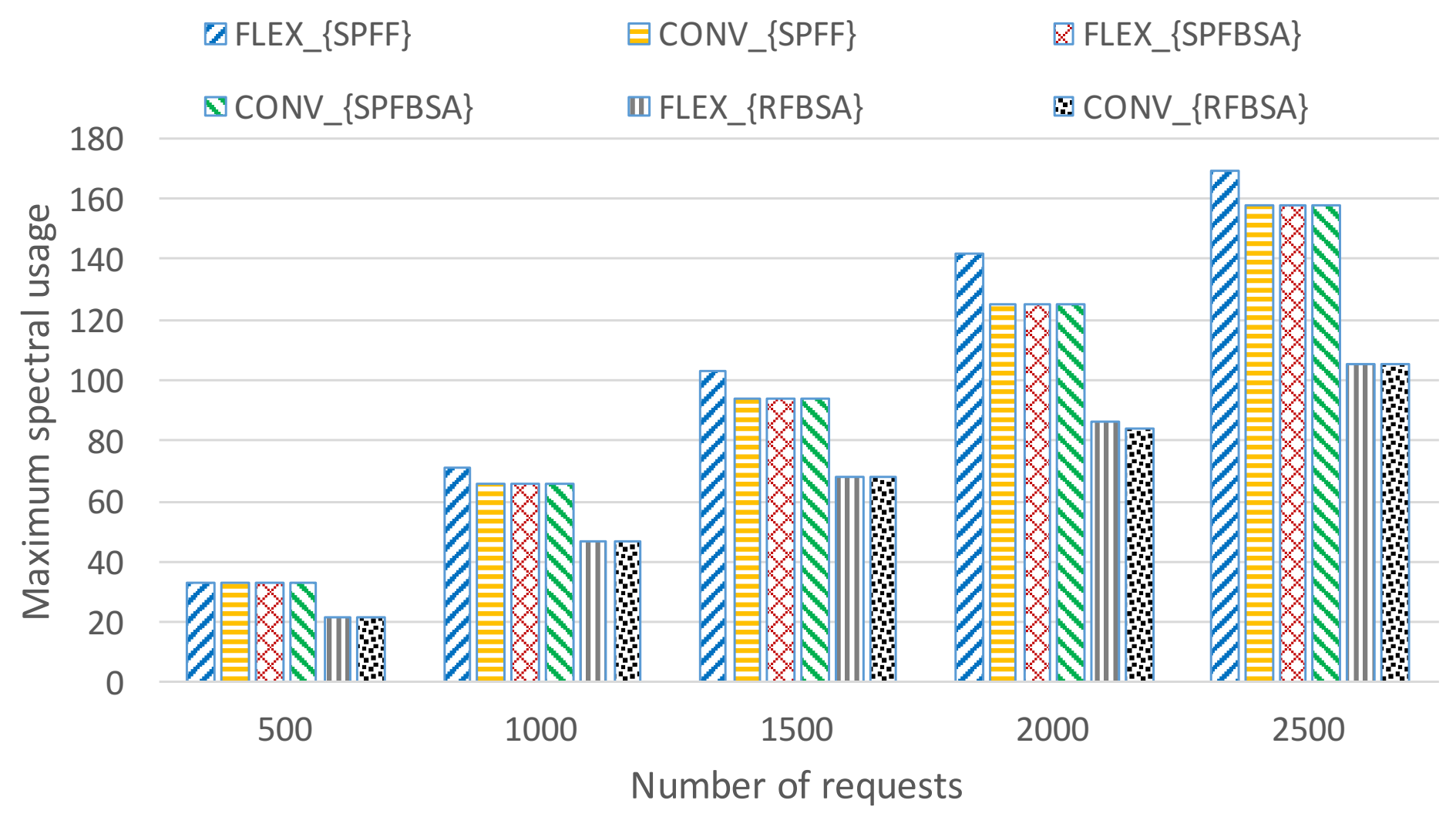

Figure 6: Performance comparison results for NSF network (F=[5,10]).

Conclusion

The proposed cost-function-pluggable auxiliary layered-graph framework is capable of dealing with the RFBSA problem with different objective functions by using different cost functions. Cost functions and parameter settings for other objectives as well as dynamic traffic models will be explored in future work.

Publications

- Jingxin Wu, Maotong Xu, Suresh Subramaniam and Hiroshi Hasegawa, "*Routing, Fiber, Band, and Spectrum Assignment (RFBSA) for Multi-granular Elastic Optical Networks*," accepted by **ICC**, 2017.