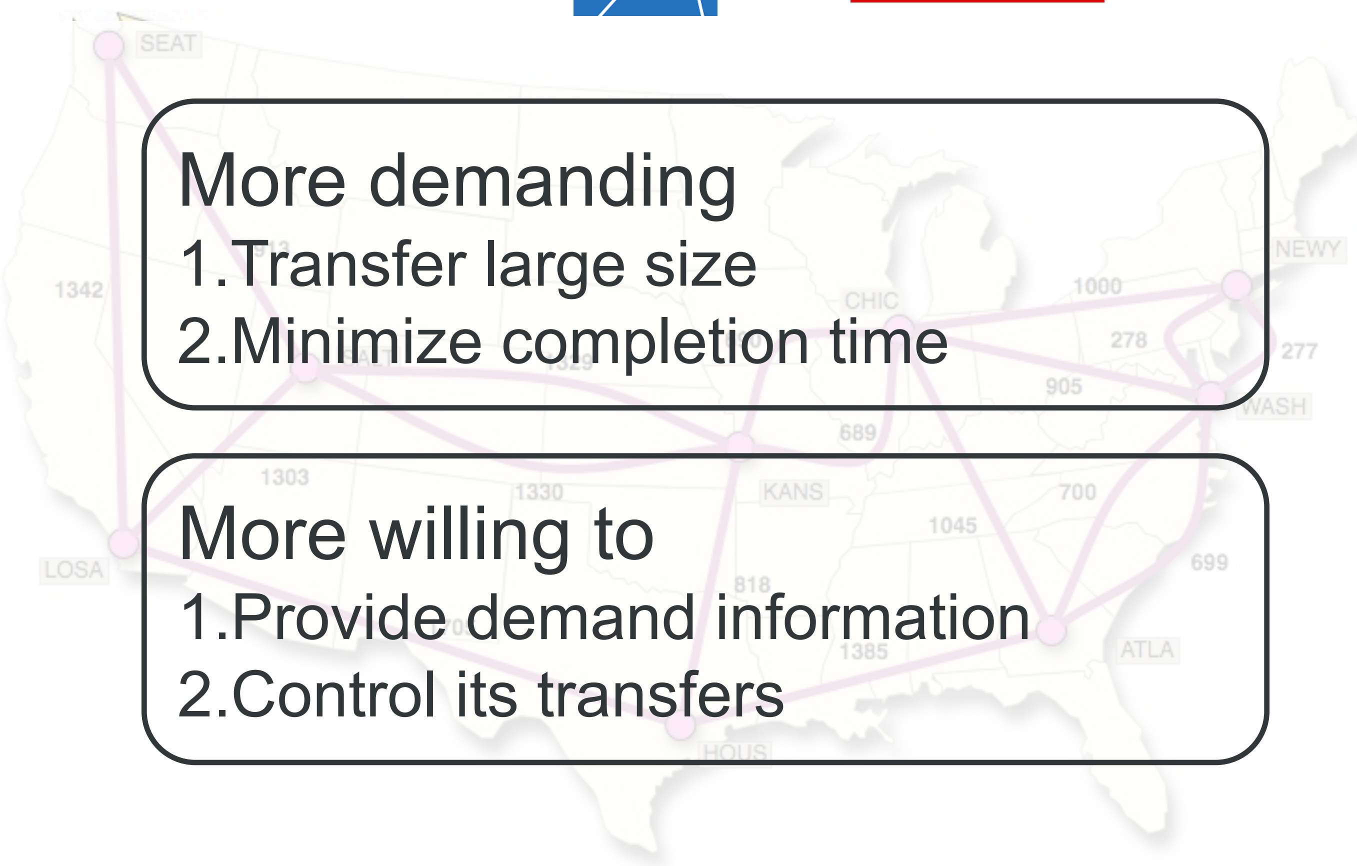
The Demand of Bulk Transfers over WAN

More demanding

1. Transfer large size
2. Minimize completion time

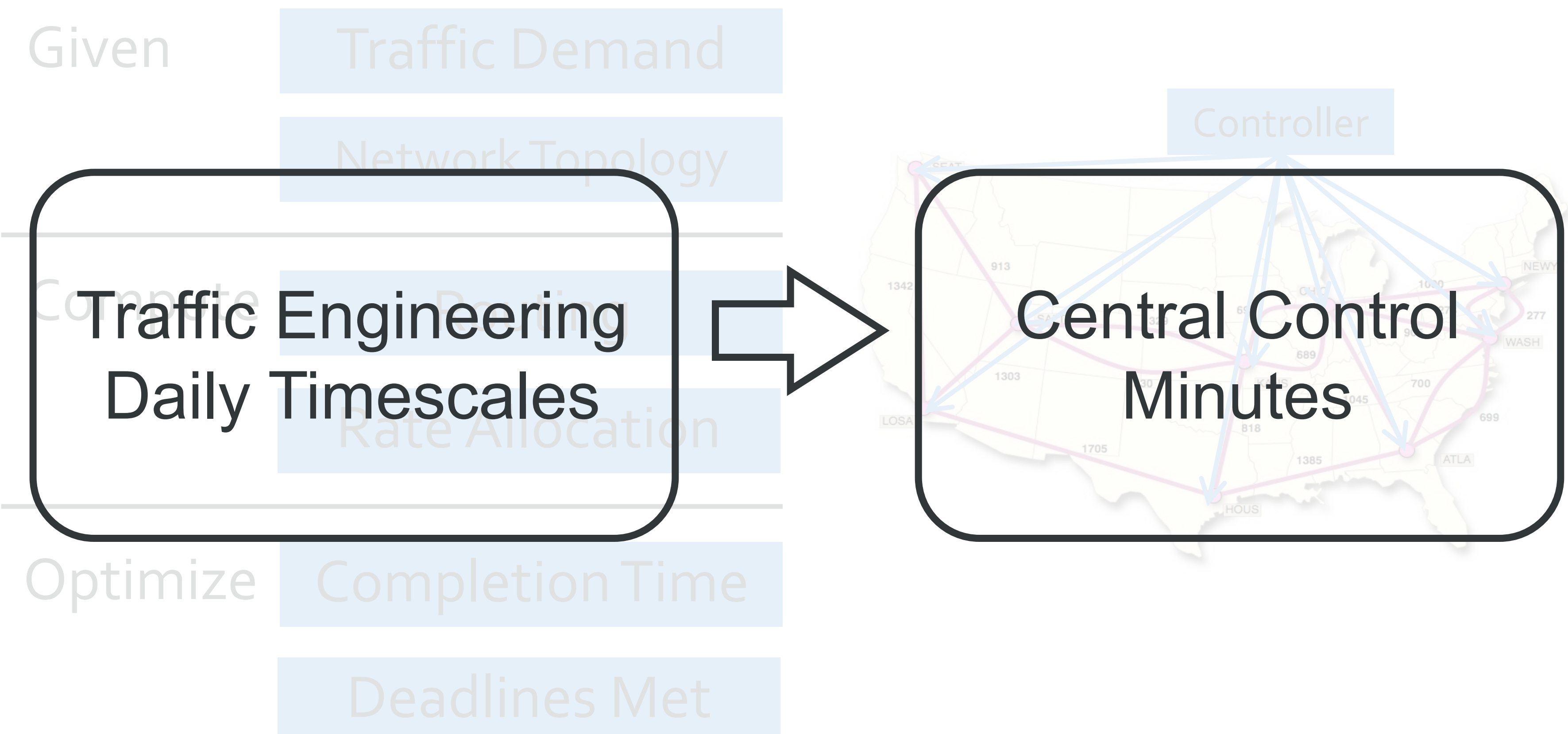
More willing to

1. Provide demand information
2. Control its transfers

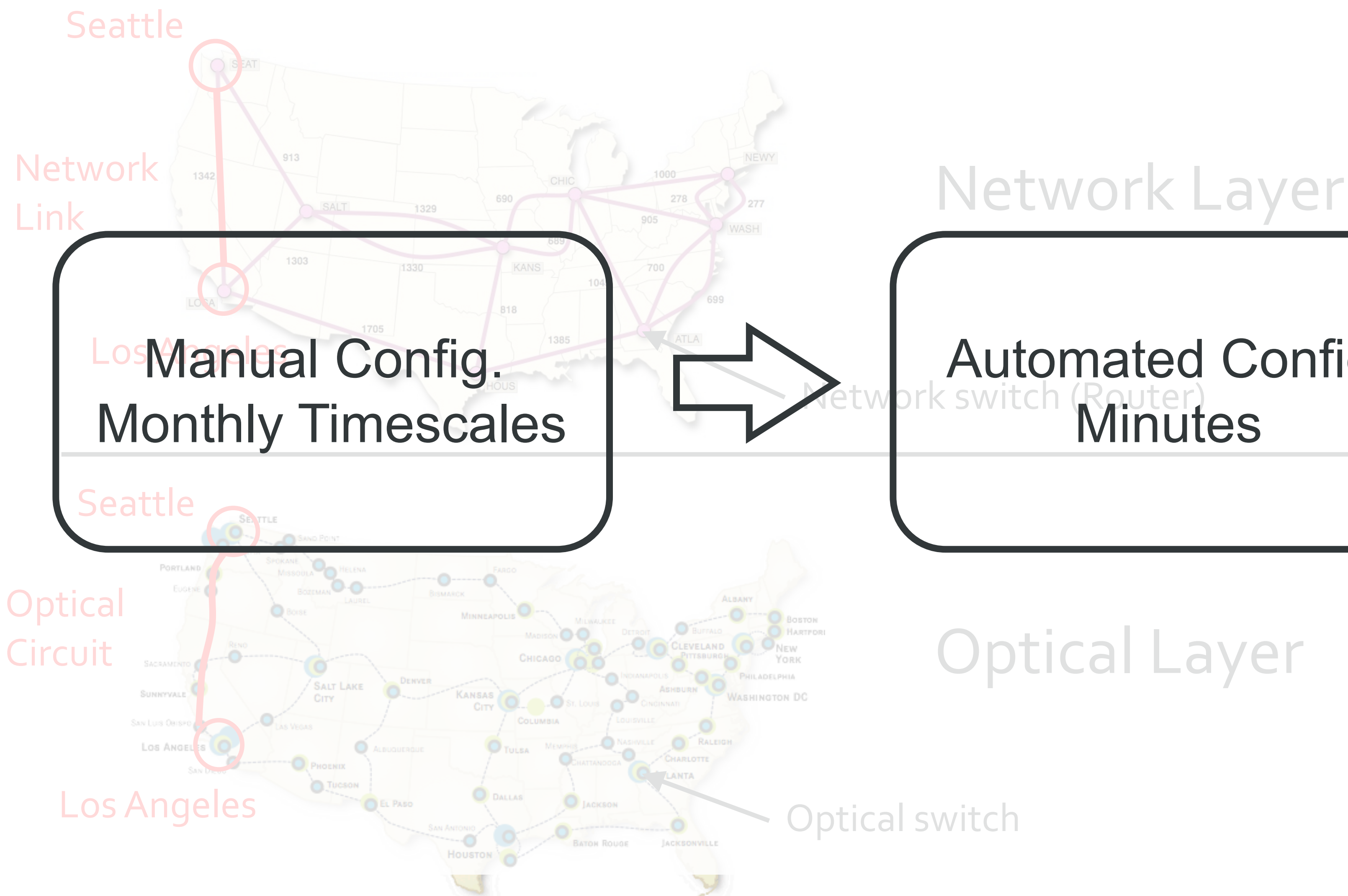


Software-Defined Networking (SDN) in WAN

Global traffic engineering with centralized control, e.g., Google B4, Microsoft SWAN



Network Layer over Optical Layer



Manual Config.
Monthly Timescales

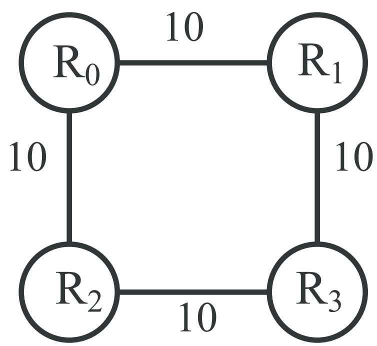
Automated Config.
Minutes

Technology Trends

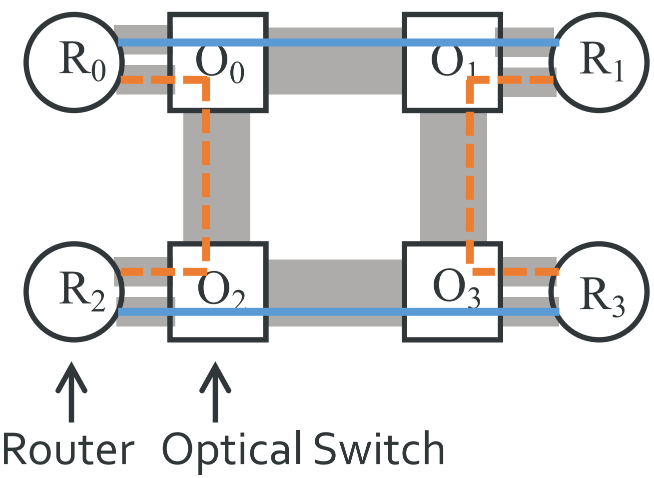
- Bulk-transfer applications with demand information
- Fast centralized control with SDN
- Fast reconfigurable optics

Reconfigure Optical Layer to Change Network-Layer Topology

Configuration A



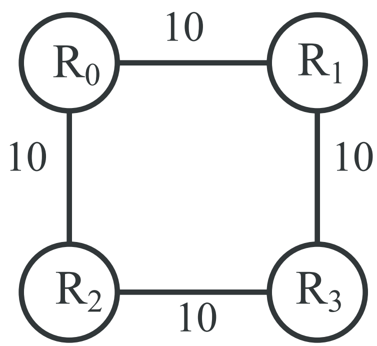
Network Layer



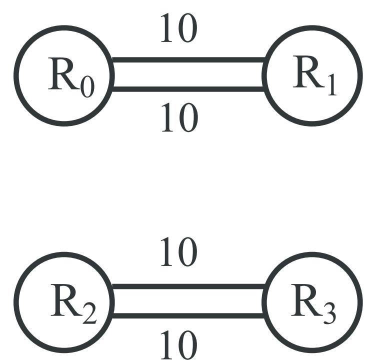
Optical Layer

Reconfigure Optical Layer to Change Network-Layer Topology

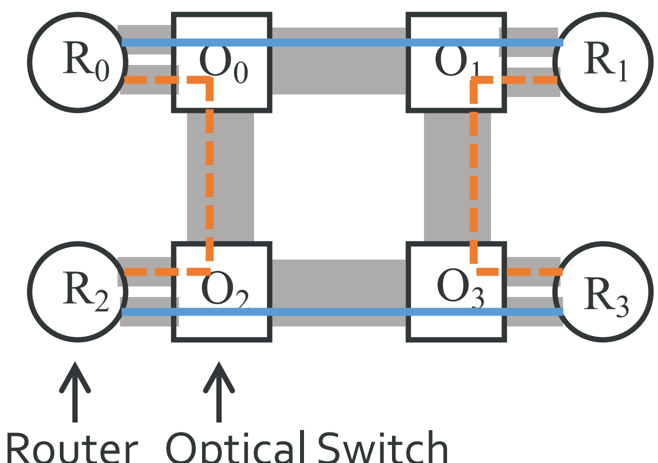
Configuration A

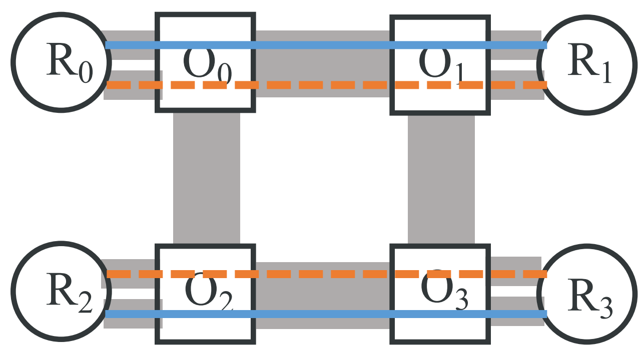


Configuration B



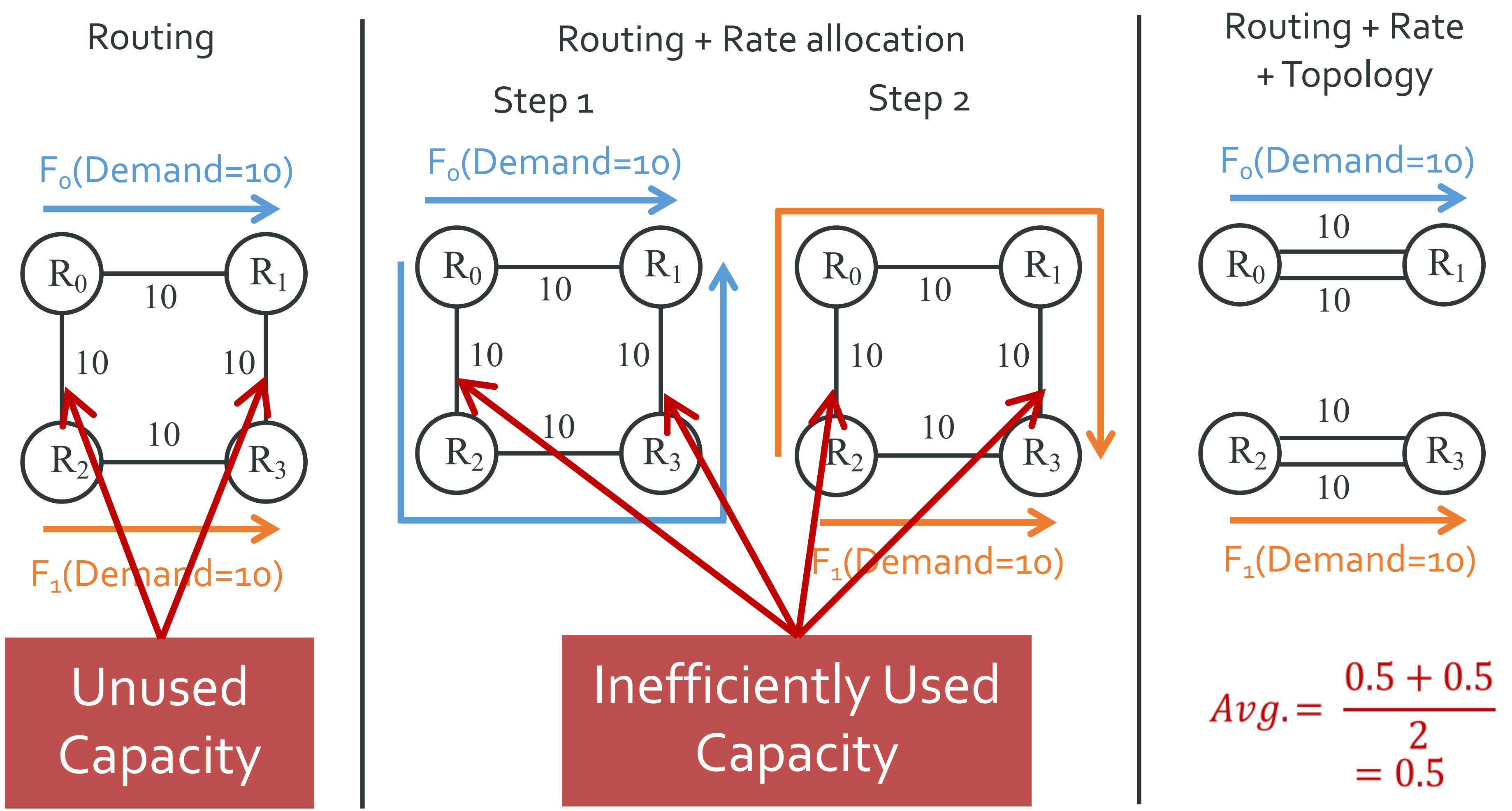
Network Layer





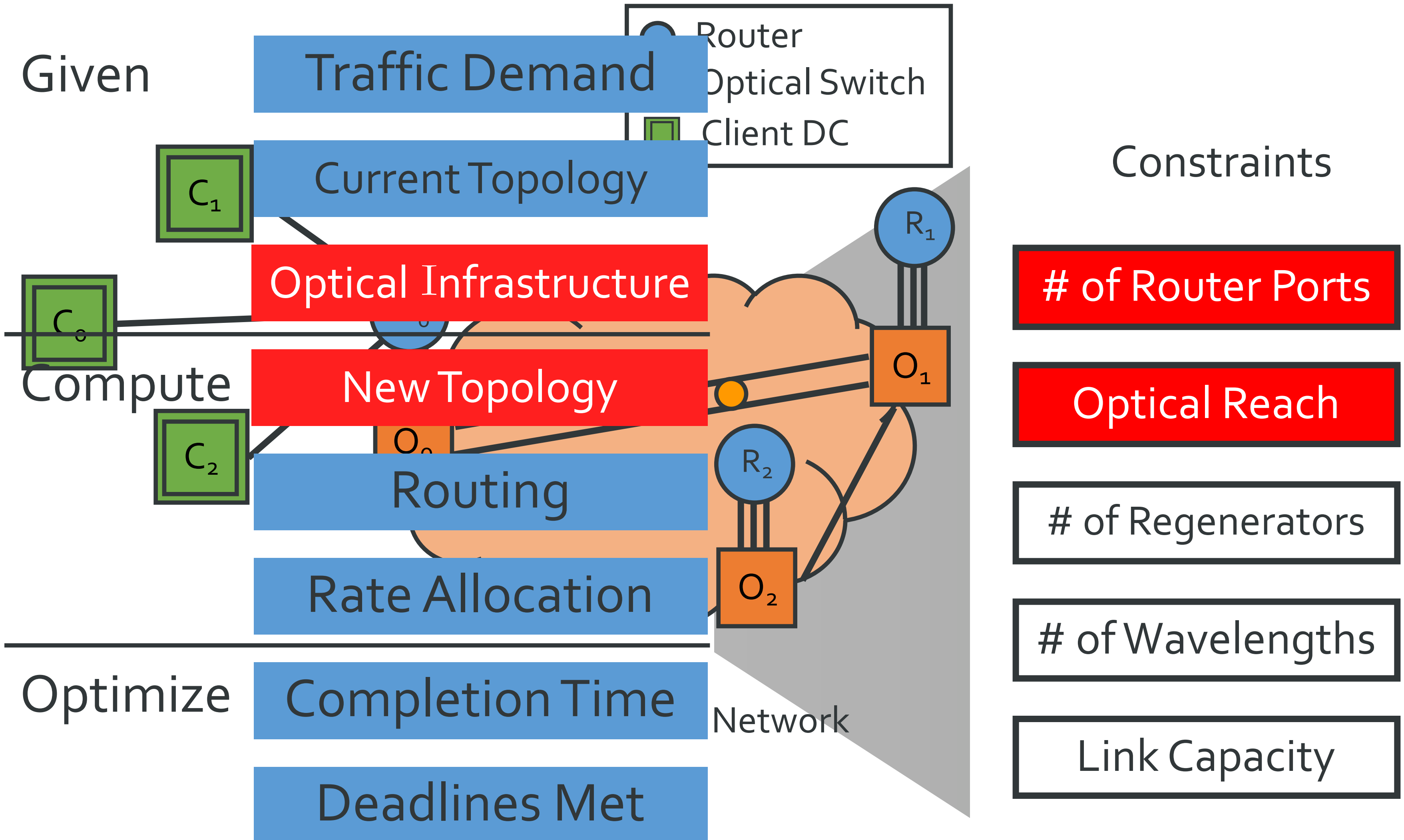
Optical Layer

Reduce Average Transfer Completion Time



Joint Optimization and Challenges

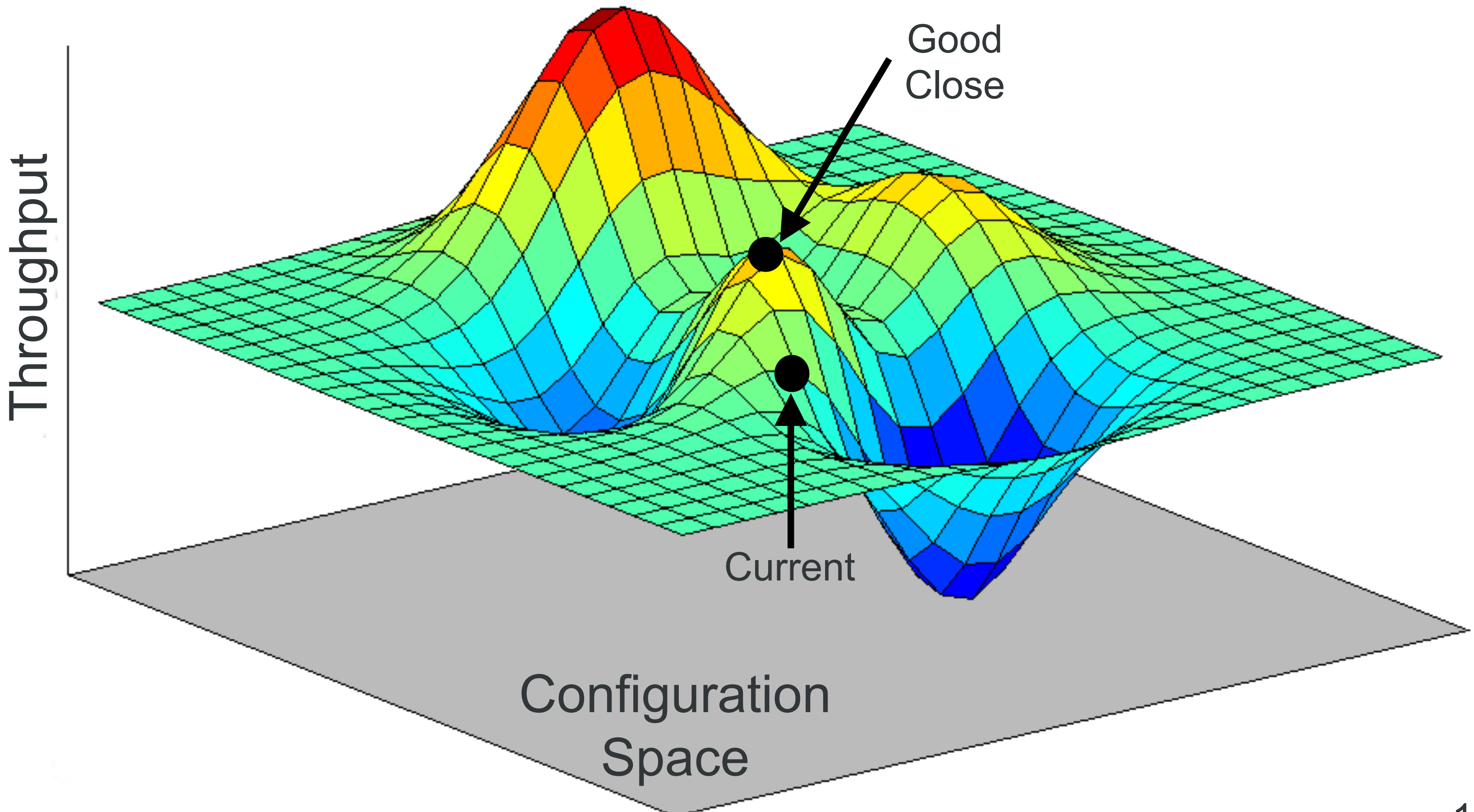
Joint Optimization



Challenges

- **Efficient joint** optimization
  - Routing
  - Rate allocation
  - Topology
- **Transition gracefully**
  - Minimize disruption during update

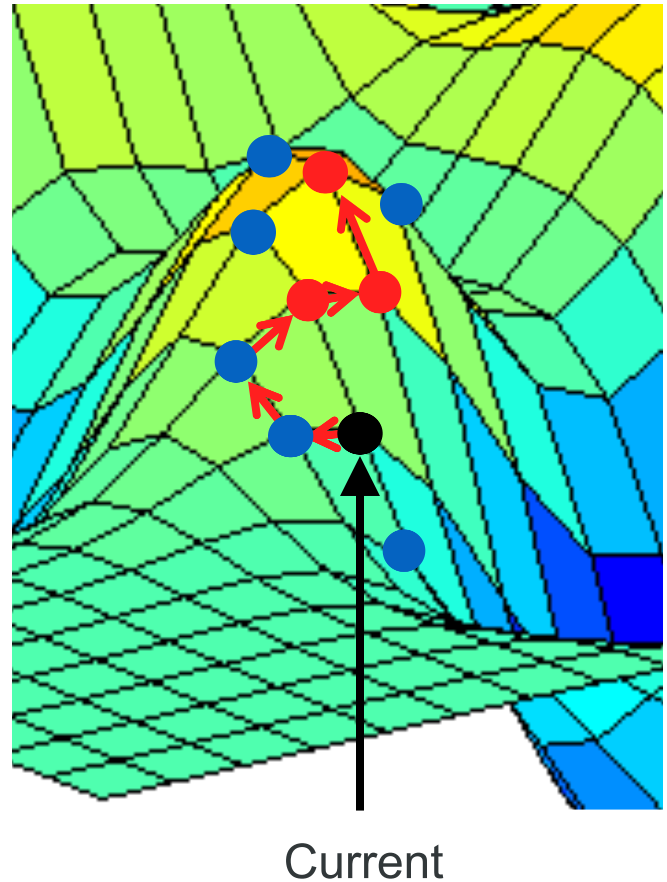
Finding Good Configuration with Small Change



Simulated Annealing Algorithm

Choose Random Neighbor

Evaluate Neighbor



Owan's Solution Overview

Choose Random Neighbor

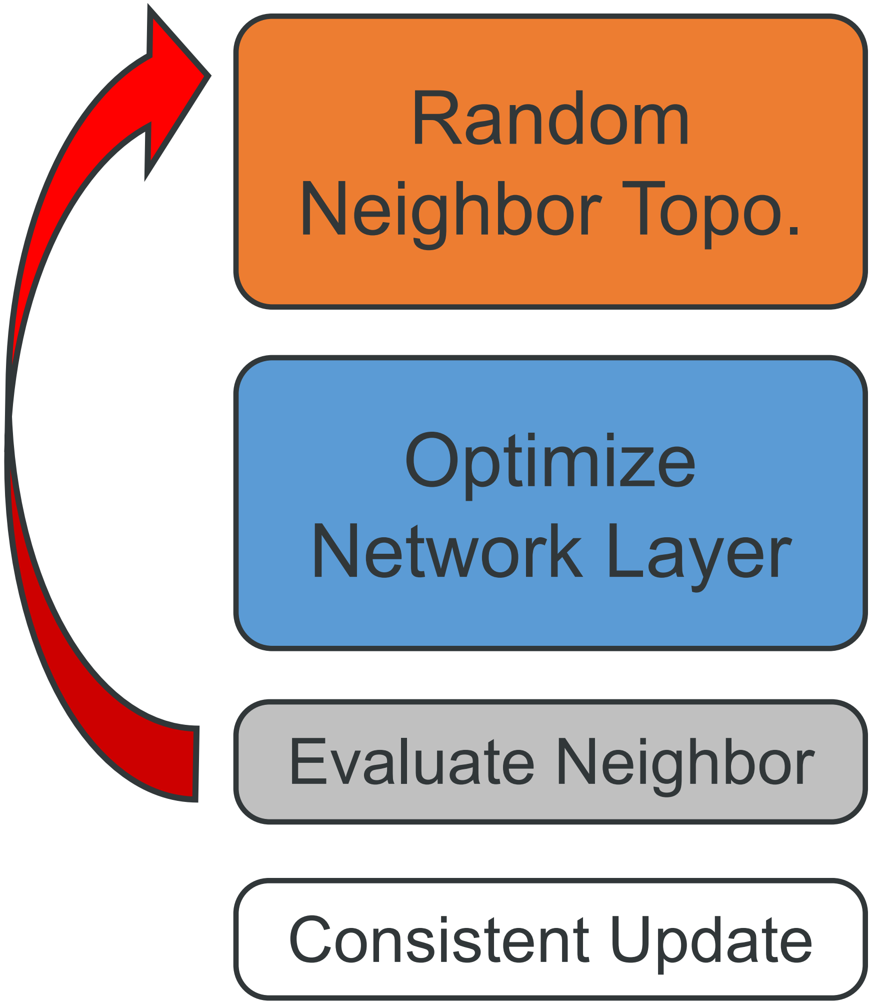
Evaluate Neighbor

Consistent Update

- Joint optimization efficiently
- Avoids disruption

Owan Algorithm

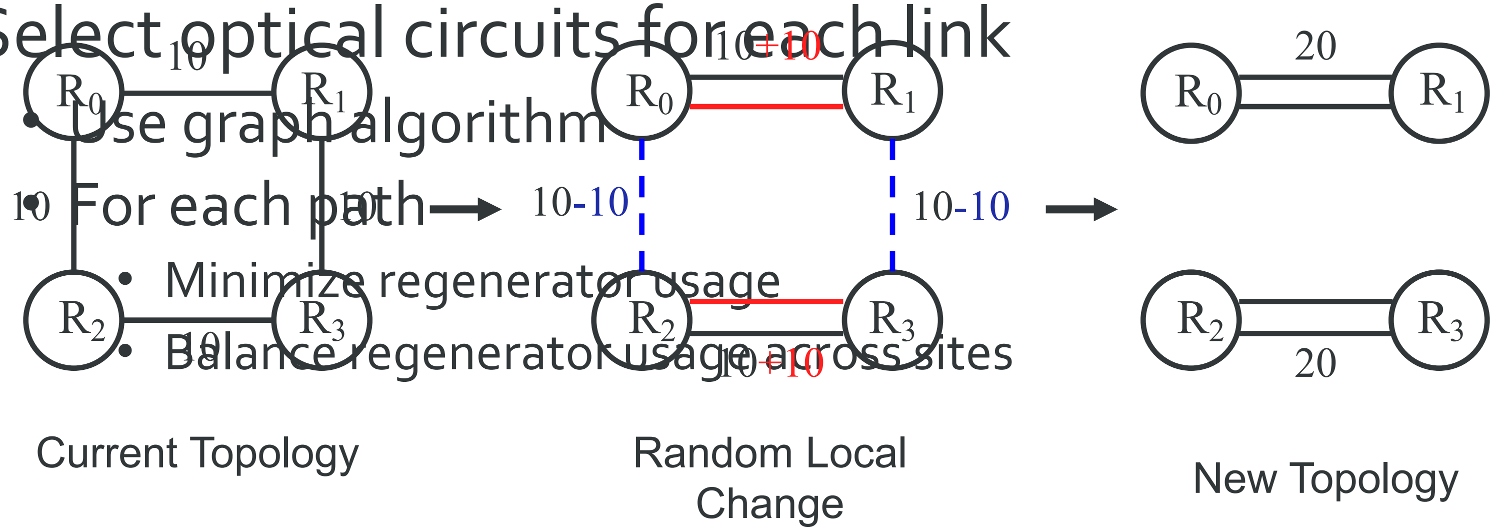
Random Neighbor Topology



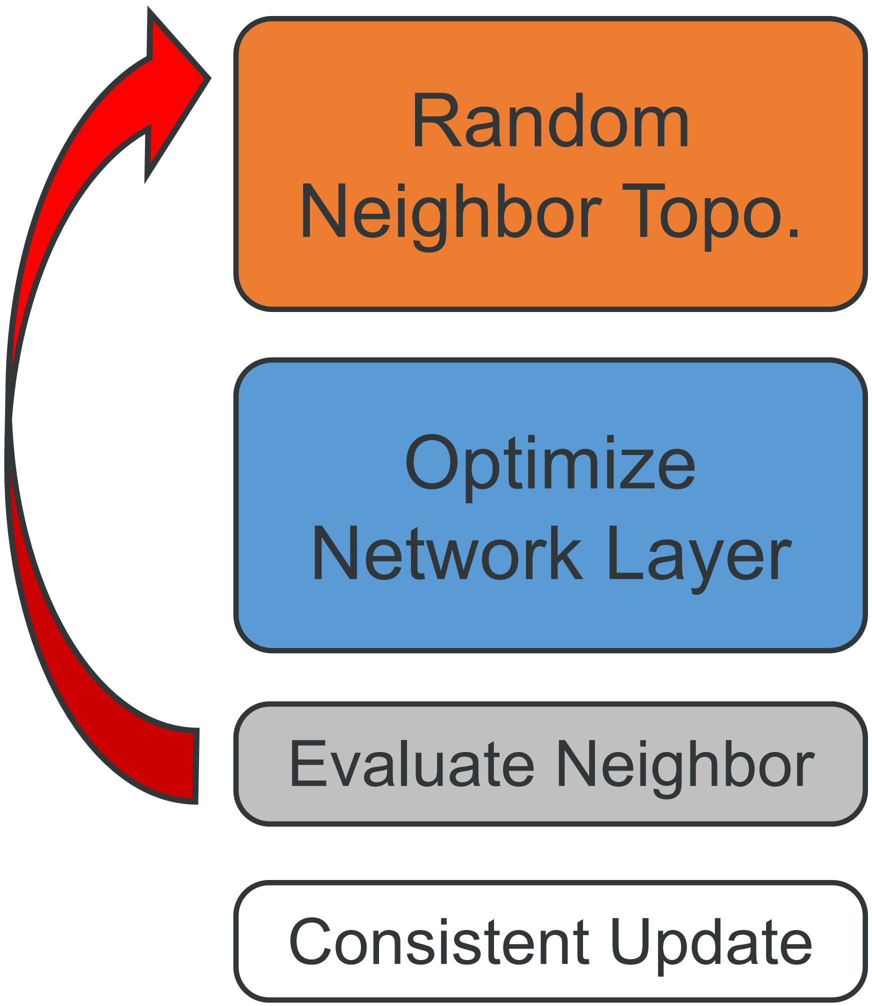
1. Make random local change
2. Select optical circuits

Random Neighbor Topology

- Make random local change
  - Minimize changes to the network
  - Satisfy the port number constraints
- Select optical circuits for each link
  - Use graph algorithm
  - For each path
    - Minimize regenerator usage
    - Balance regenerator usage across sites



Optimize Network Layer



1. Routing
2. Rate allocation

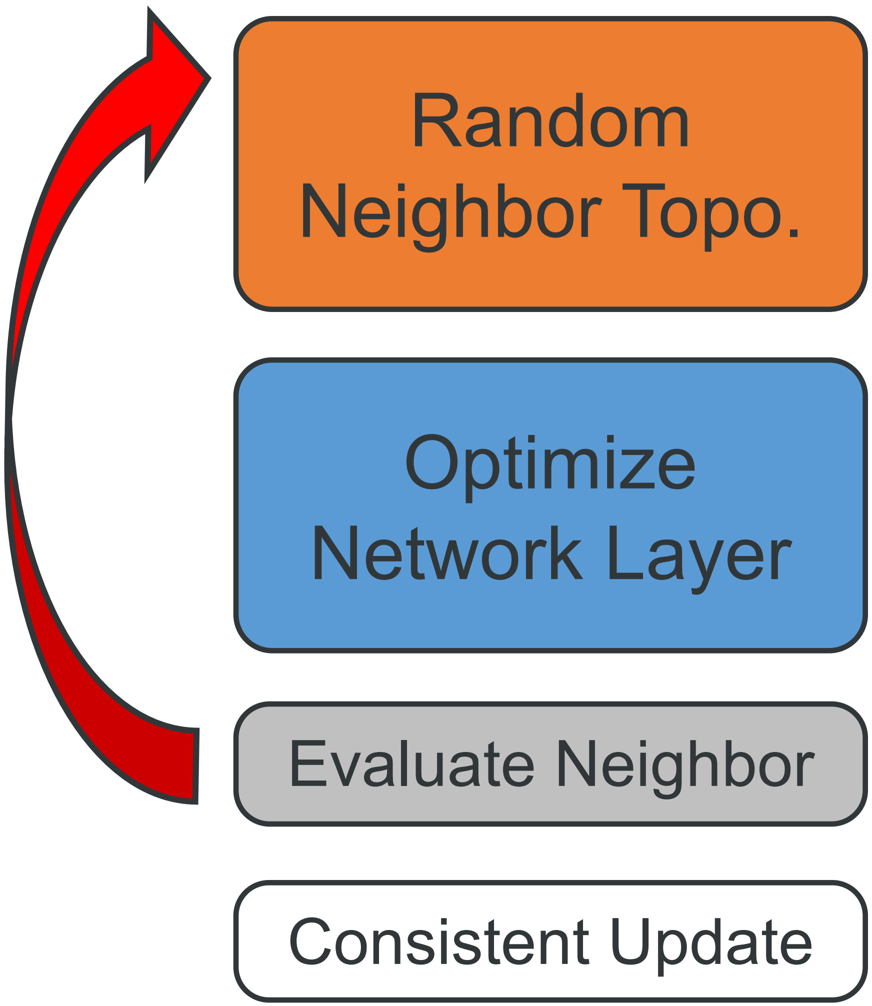
Schedule Transfers on the New Topology

- Order transfers with classic scheduling disciplines

SJF	EDF	……
↓	↓	↓
Avg. Transfer Completion Time	# of Deadlines Met	Other Objective

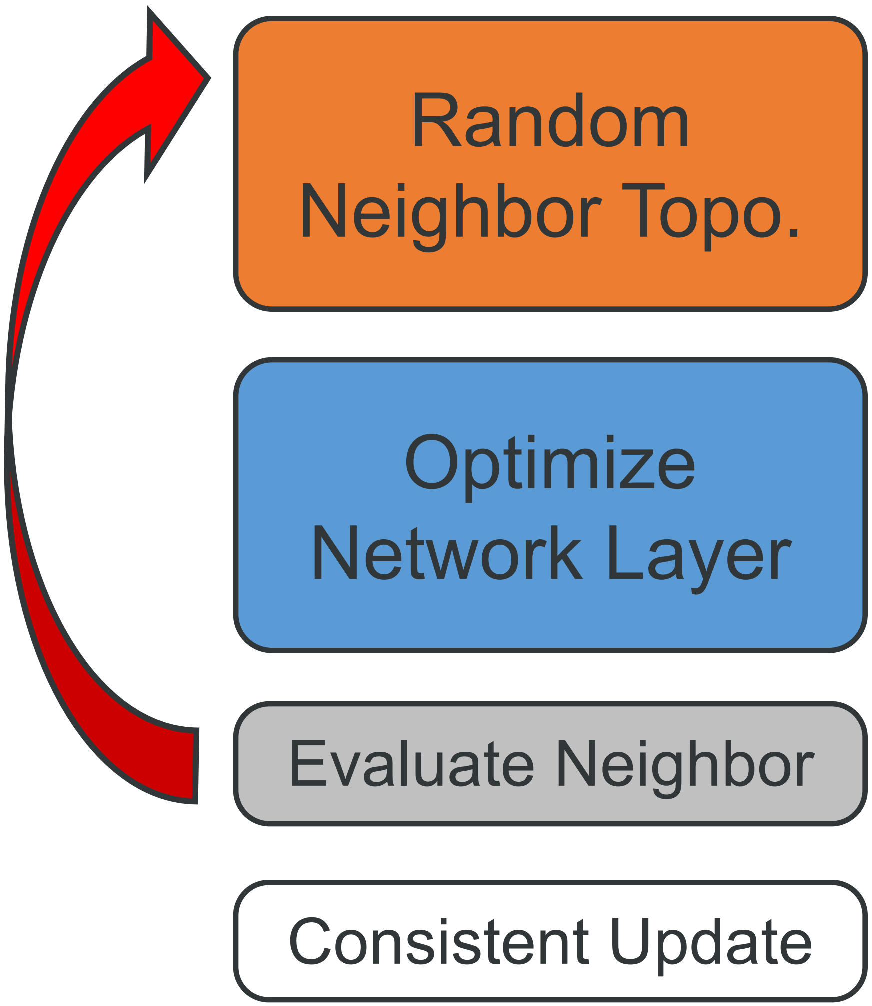
- Prioritize short paths in rate allocation

Evaluate Neighbor Topology



- Throughput: sum of rates

Consistent Update

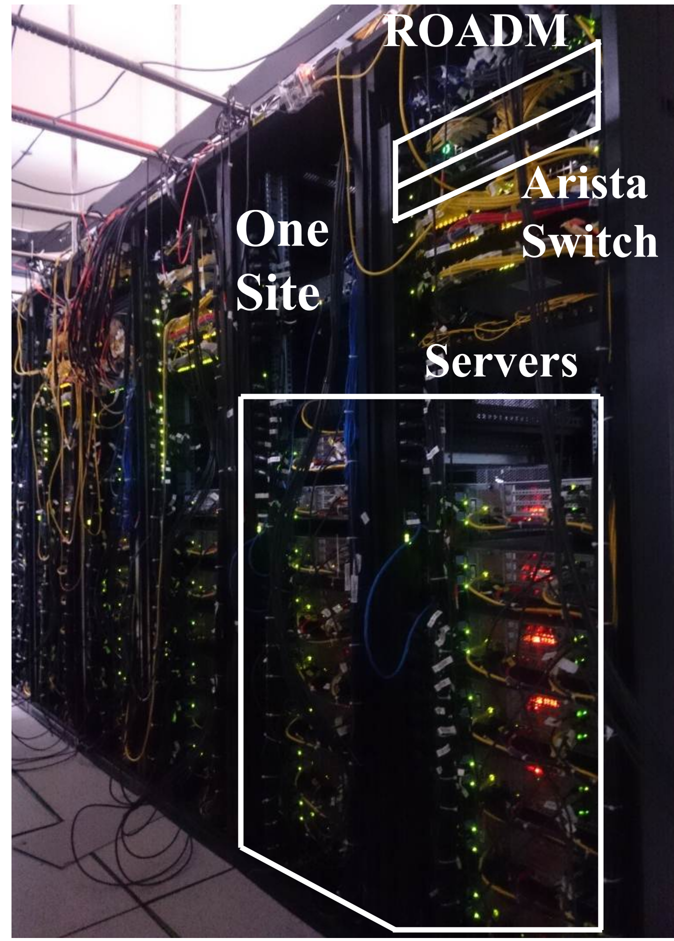


- Dependencies of operations

Implementation and Evaluation

Testbed Implementation

- 9 Sites
- Emulating Internet2 network
- 135 servers
  - Two 6-core Intel E5-2620v2
  - 10GE



Evaluation

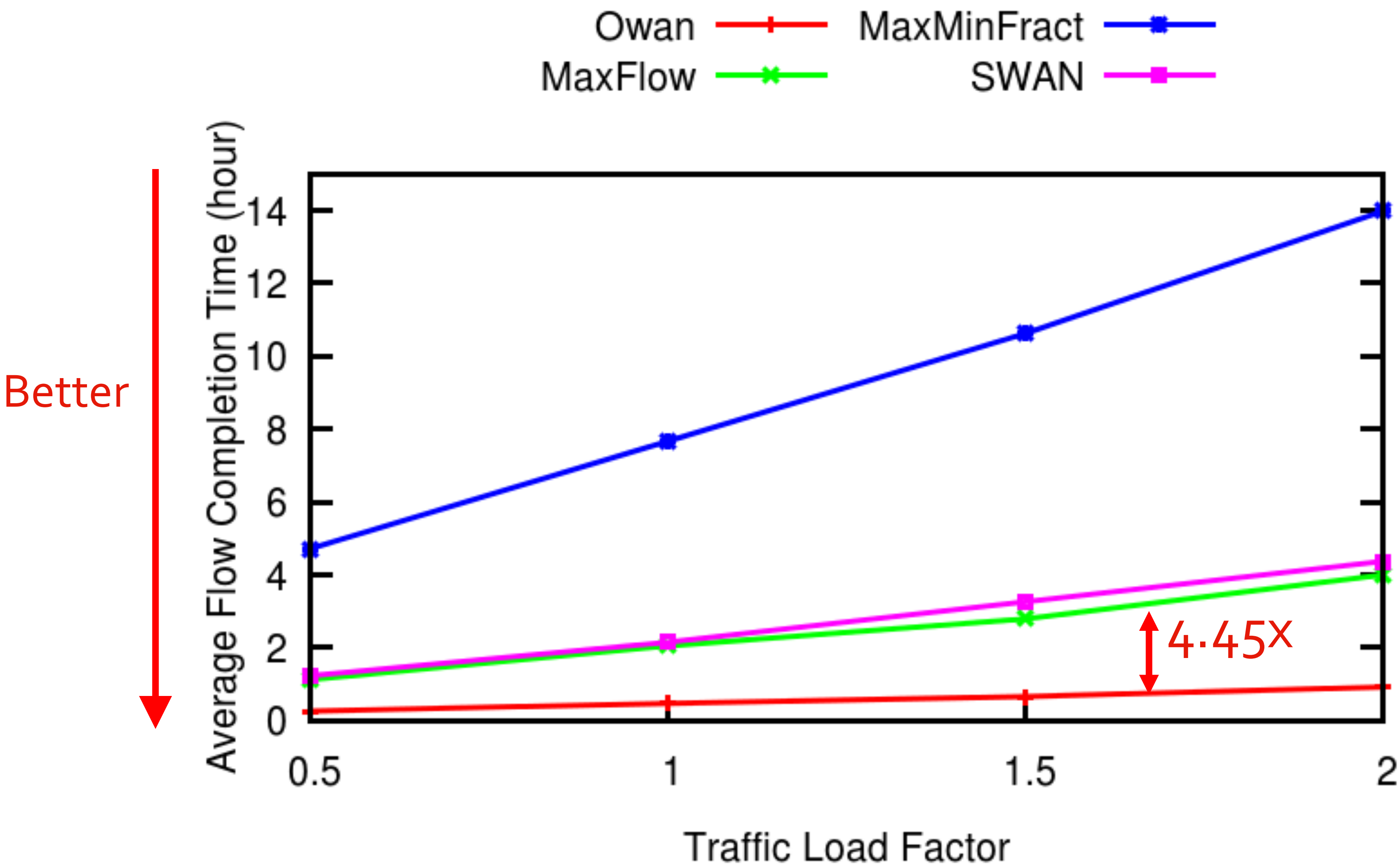
- Workload
  - Generate transfers for 2 hours
  - Draw transfer size from exponential distribution
    - Mean 500GB/5TB for testbed/simulation
- Evaluation
  - Testbed experiments, with 9 sites
  - Large-scale simulations, with about 40 sites
- Results
  - Average transfer completion time: 3.5-4.4x
  - Number of transfers that meet deadlines: 1.1-1.3x

Deadline-Unconstrained Traffic

- Performance metric
  - Transfer completion time
- Other approaches
  - MaxFlow
  - MaxMinFract
  - SWAN[1]

[1] Hong, Chi-Yao, et al., Achieving High Utilization with Software-Driven WAN, SIGCOMM 2013

Better Average Completion Time

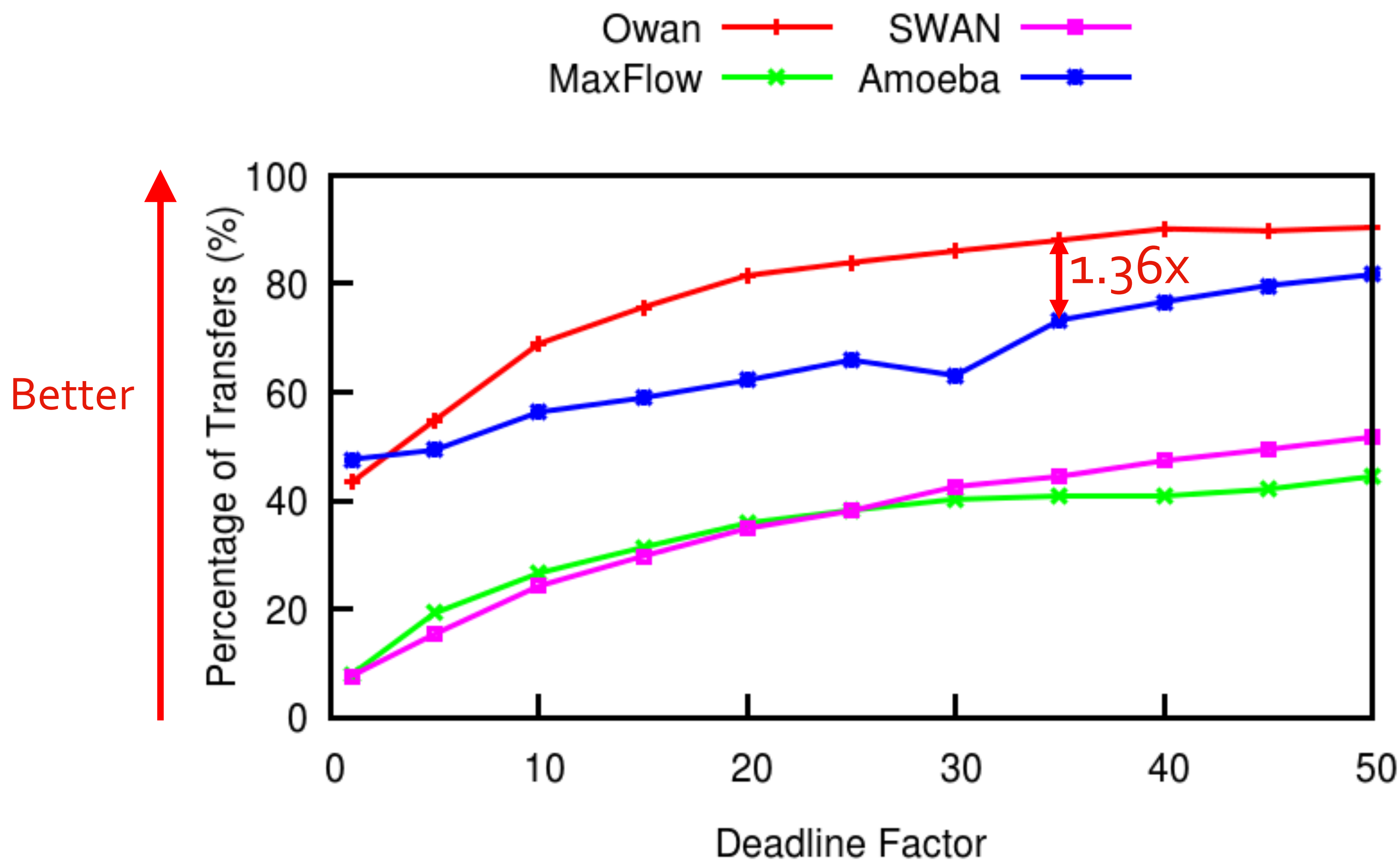


Deadline-Constrained Traffic

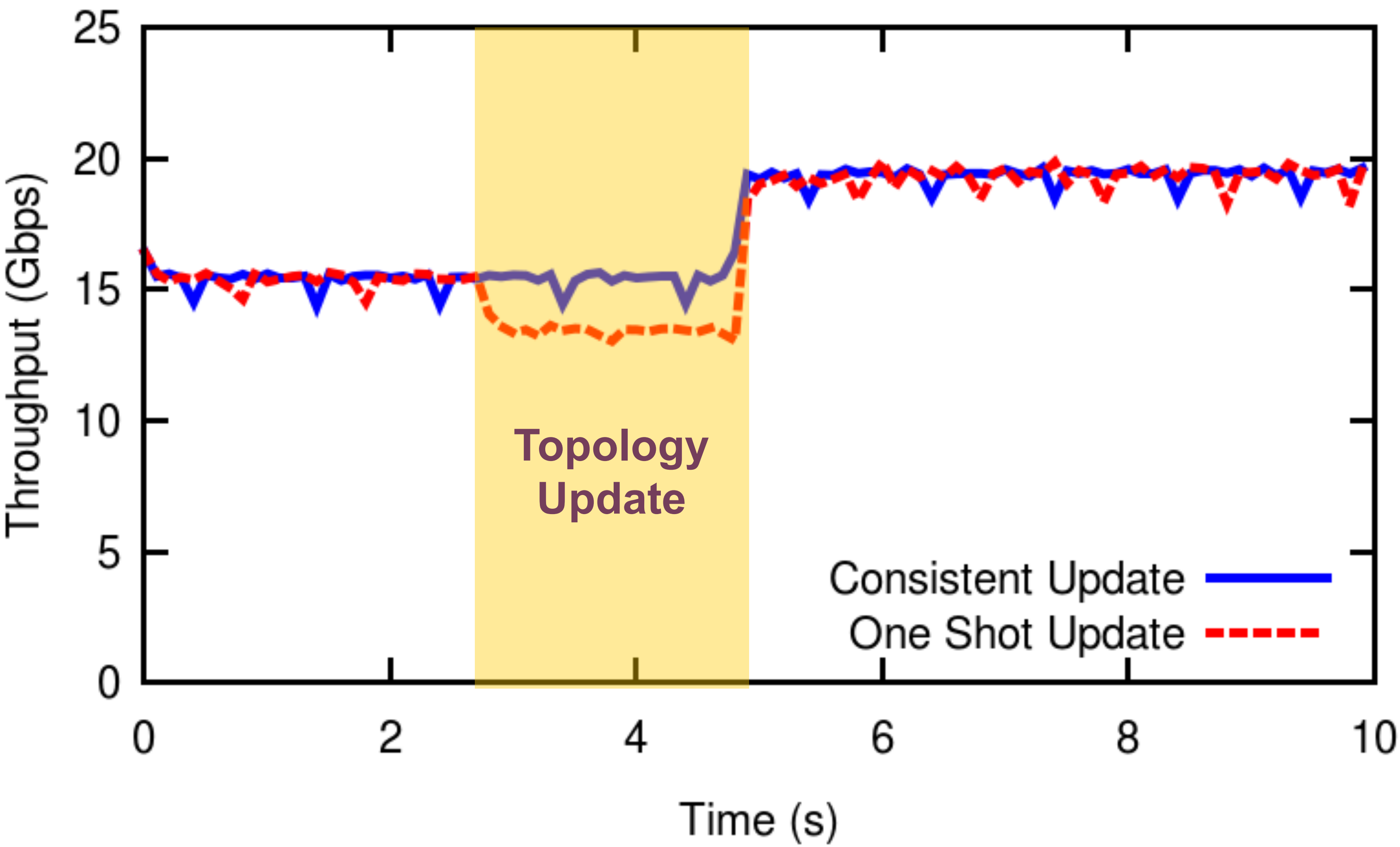
- Performance metric
  - Percentage of transfers that meet deadlines
  - Amount of bytes that finish before deadlines
- Other approaches
  - Deadline-unconstrained approaches
  - Amoeba[1]

[1] Zhang, Hong, et al., Guaranteeing deadlines for inter-datacenter transfers, EuroSys 2015

More Transfers Meet Deadlines



Consistent Update Avoids Disruptions



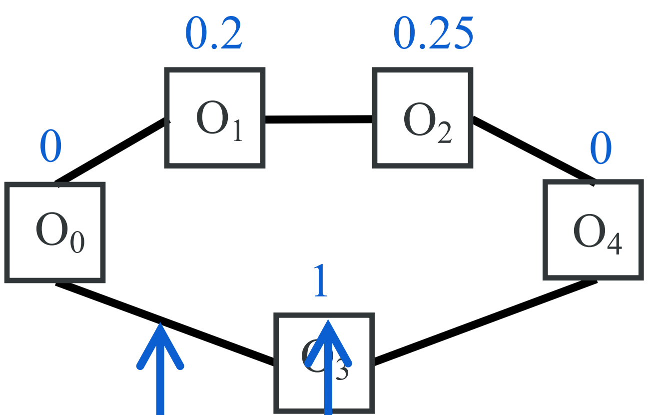
Conclusions

- Optical control improves WAN performance
- Efficient algorithms for joint optimization
- Transition gracefully

Thanks!
Q&A

Build Optical Circuits for Each Link

- Build regenerator graph
- Balance regenerator consumption



Distance <= Optical Reach

Inverse of # Regenerators

Goal: Find path with min total node weight

Shortest path problem on directed graph

Cross-Layer Optimization at Each Time Slot