OptFlow: A Flow-based Abstraction for Programmable Topologies

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Wide/Regional/Metro-Area Networks are not Static
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Closer look: Optical components

- Dense Wavelength Division Multiplexing (DWDM)
  - > 100 wavelengths (e.g. 100Gbps) per fiber
Closer look: Optical components

- Dense Wavelength Division Multiplexing (DWDM)
  - > 100 wavelengths (e.g. 100Gbps) per fiber

- Wavelengths can be steered at connection points
  - By ROADMs (reconfigurable add/drop multiplexers)
Intuition: Move wavelengths
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wavelength capacity = 1
Intuition: Move wavelengths

wavelength capacity = 1
Intuition: Move wavelengths

wavelength capacity = 1

throughput: 1+1
Intuition: Move wavelengths

```

Intuition: Move wavelengths

wavelength

1

1

1

1

1

1

1

1

throughput: 1+1

throughput: 2+2
```
Intuition: Move wavelengths

demand-aware capacity (wavelengths)
Intuition: Move wavelengths

Topology Programmability (TP) + Traffic Engineering (TE) > TE

demand-aware capacity (wavelengths)
How to leverage Topology Programmability (TP)?

• Variant #A: Optimize TP and Traffic Engineering (TE) separately?
  ◦ Inefficient, misses opportunities (recall last slide)

• Variant #B: Redesign TE to include TP?
  ◦ Tedious, operators are reluctant

• Variant #C: Don’t change TE, still incorporate TP!
  ◦ Abstractions!
How to incorporate current Traffic Engineering (TE)?

Abstractions

Unmodified Traffic Eng. \[\downarrow\] Augmented Topology

Flow routing

Reconfiguration
How to design the Abstraction?

Setting in our example:
• Every node supports 2 wavelengths
• Every edge supports 2 wavelengths
How to design the Abstraction?

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Idea: u should only send 2 real units of traffic
• Implement fake flows that block capacity
  • Represent dual wavelength assignment
  • TEs can deal with flows
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Idea: u should only send 2 real units of traffic
- Implement fake flows that block capacity
  - Represent dual wavelength assignment
  - TEs can deal with flows

TE performs TP by routing both flow types
- Fake flows from u to x or v
- Real traffic from u to x
Intuition for the Abstraction

Setting in our example:
- Every node supports 2 wavelengths
- Every edge supports 2 wavelengths
- $u$ wants to send traffic to $x$
- $v$ wants to send traffic to $w$
Intuition for the Abstraction

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- $u$ wants to send traffic to $x$
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Abstraction intuition:
- Every node sends 2 unit flows to neighbors
- Every edge has a capacity of 2
- $u$ still wants to send traffic to $x$
- $v$ still wants to send traffic to $w$
Intuition for the Abstraction

Setting in our example:
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- \( u \) wants to send traffic to \( x \)
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Abstraction intuition
- Every node sends 2 unit flows to neighbors
- Every edge has a capacity of 2
- \( u \) still wants to send traffic to \( x \)
- \( v \) still wants to send traffic to \( w \)

Result:
- 2 fake flows between \( u,v \) & \( x,w \)
- No capacity left between \( u,v \) & \( x,w \)
- 2 units of capacity for \( u,v \) & \( x,w \)
- Real throughput of: 2+2
Intuition for the Abstraction

- Every node supports 2 wavelengths
- Every edge supports 2 wavelengths
- u wants to send traffic to x
- v wants to send traffic to w

Setting in our example:
- Node u and v send 2 unit flows to neighbors
- Node x and w has a capacity of 2

Abstraction intuition:
- Every node sends 2 unit flows to neighbors
- Every edge has a capacity of 2

• u still wants to send traffic to x
• v still wants to send traffic to w

Result:
- 2 fake flows between u, v & x, w
- No capacity left between u, v & x, w
- 2 units of capacity for u, v & x, w
- Real throughput of: 2+2
Intuition for the Abstraction

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TE performs TE+TP on abstraction details in the paper
Takeaway

- TE performs TE and TP due to the abstraction
  - Details in the paper

- Consistent update methods for flows carry over
  - Abstraction enables cross-layer updates for free

- Support for major TE types (max. throughput, k-shortest path routing etc.)
Testbed: Demonstration of TP in Practice

**Physical setup of our testbed**

![Physical setup image]

**Logical setup**

![Logical setup diagram]
Experiment: Demonstration of TP in Practice

- Traffic from A to C (via A-C and A-B-D-C)
Experiment: Demonstration of TP in Practice

- Traffic from A to C (via A-C and A-B-D-C)
- Fail A-B link
Experiment: Demonstration of TP in Practice

- Traffic from A to C (via A-C and A-B-D-C)
- Fail A-B link
- Controller notices cut & shifts wavelength
Simulations: k-Shortest Path Routing
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• Comparison: Standard ILP (JointOpt) vs. our approach (OptFlow)
Simulations: k-Shortest Path Routing

• Comparison: Standard ILP (JointOpt) vs. our approach (OptFlow)

| Topology            | #Nodes | #Links |
|---------------------|--------|--------|
| Google (G-Scale) [28] | 12     | 38     |
| Internet2 [30]      | 40     | 100    |
| IDN [26]            | 40     | 390    |
| AS 1221 (Telstra) [2] | 104    | 306    |
Simulations: k-Shortest Path Routing

• Comparison: Standard ILP (JointOpt) vs. our approach (OptFlow)

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OptFlow: A Flow-based Abstraction for Programmable Topologies (SOSR’20)
Our abstraction enables Traffic Engineering to leverage Topology Programming

- Main idea: represent reconfigurability as flows
- Key items evaluated in a small testbed
- Simulations show good run time performance

Outlook: Expand to

- further Traffic Engineering objectives
- include amplifiers and long-range wavelengths
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