Chisel: An optical slice of the wide-area network

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Talk's structure

Background and motivation

- Cloudifying 5G
- WAN slicing

Challenge 1

- Where do we slice the WAN?

Challenge 2

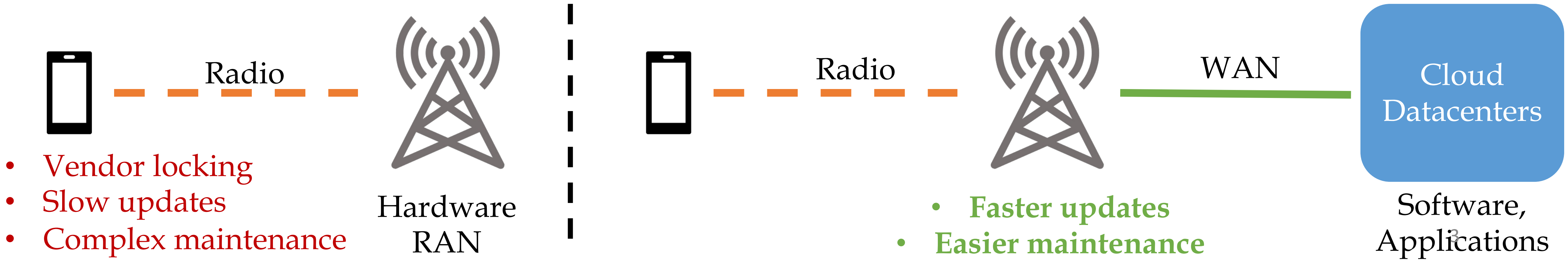
- How do we optimally slice?
- Results

Challenge 3

- Hardware implementation
- Results

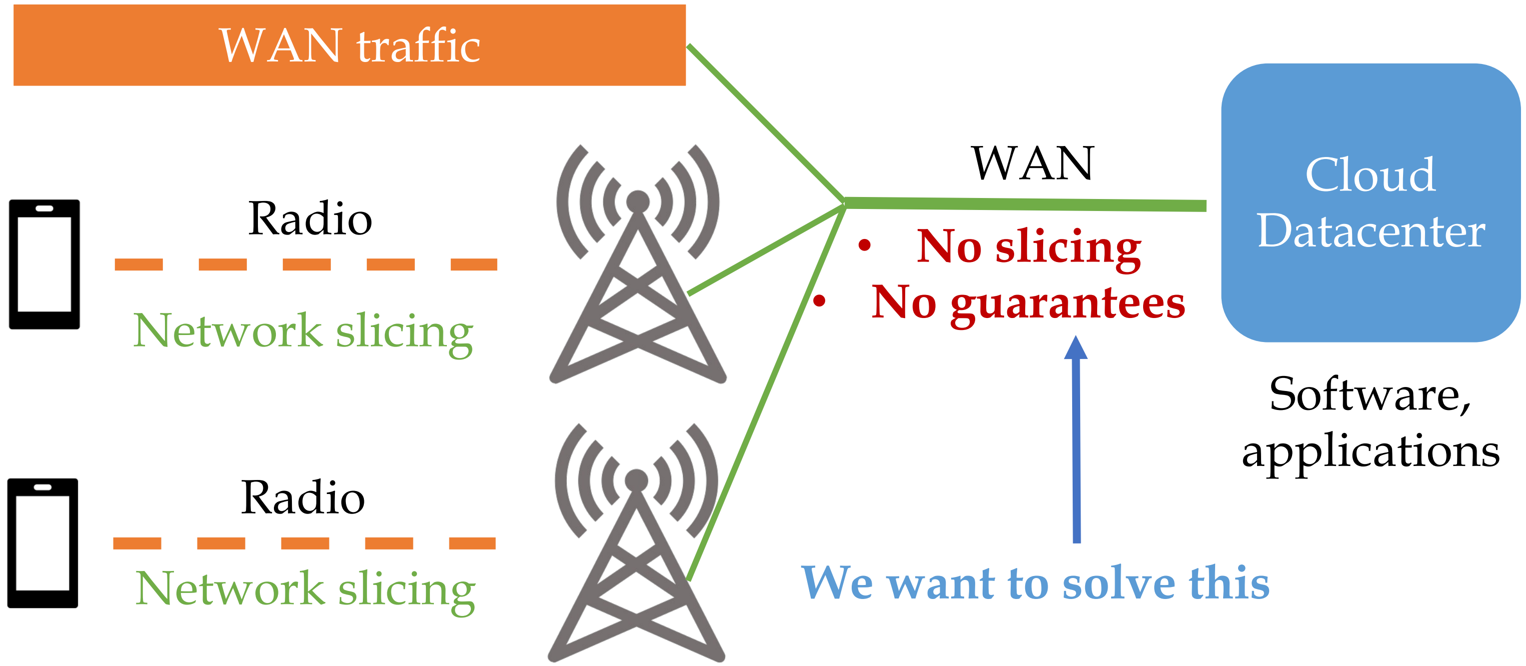
5G is ubiquitous

- 5G offers high bandwidth and is widely adopted
- Cellular providers are adopting vRAN architecture
  - Signal demodulation, FEC decoding, checksum etc.
- vRAN architecture have strict latency requirements
- 5G applications require strong network guarantees



Extending network slices to the cloud

- Network Slice: Isolated part of the network bandwidth for QoS.
- Limited to traffic between base-station and user devices (Radio).
- No guarantees from base-station to the cloud (WAN).



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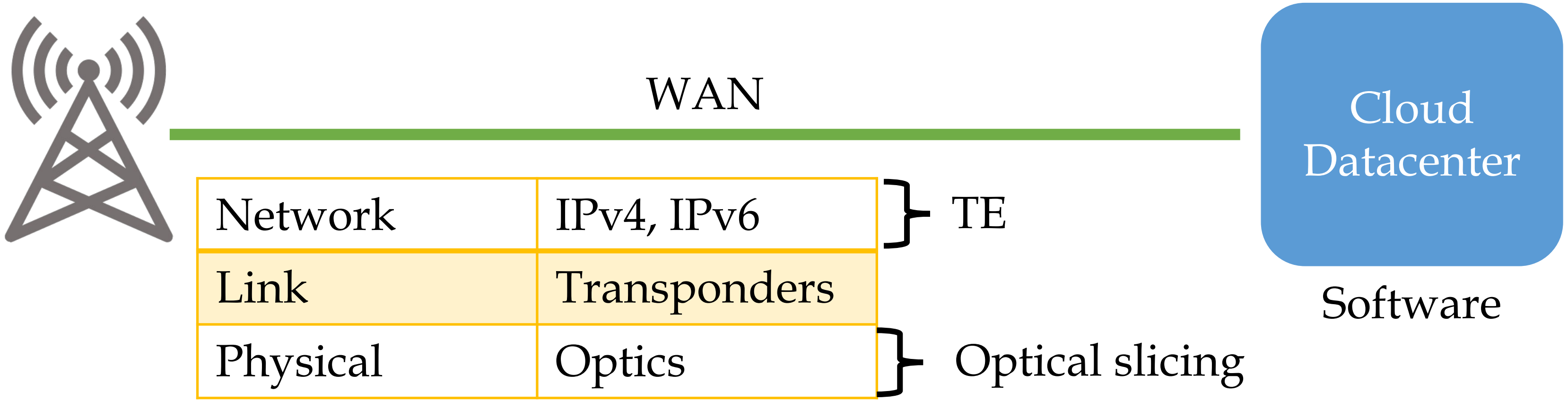
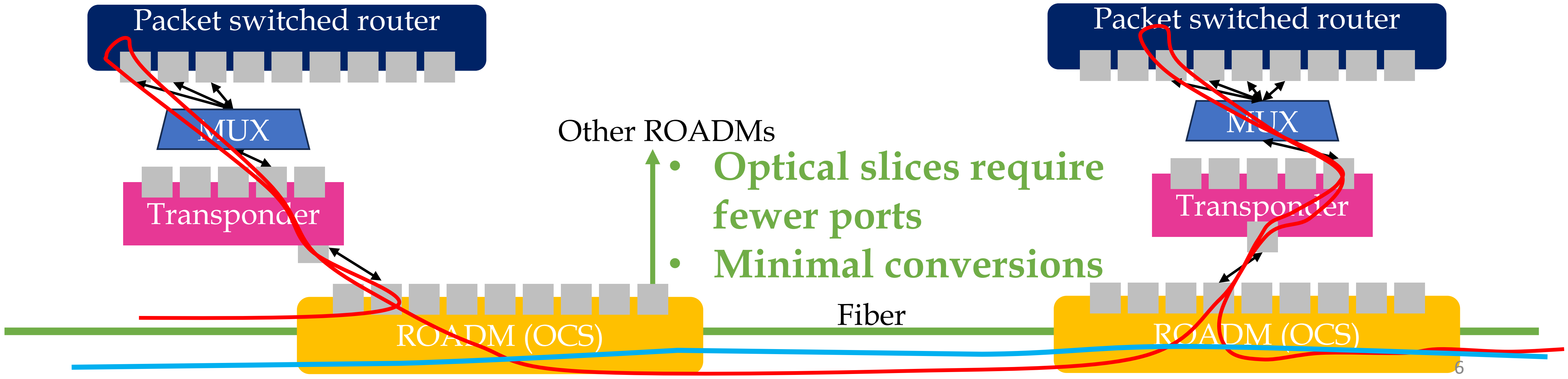
Where do we slice the WAN?

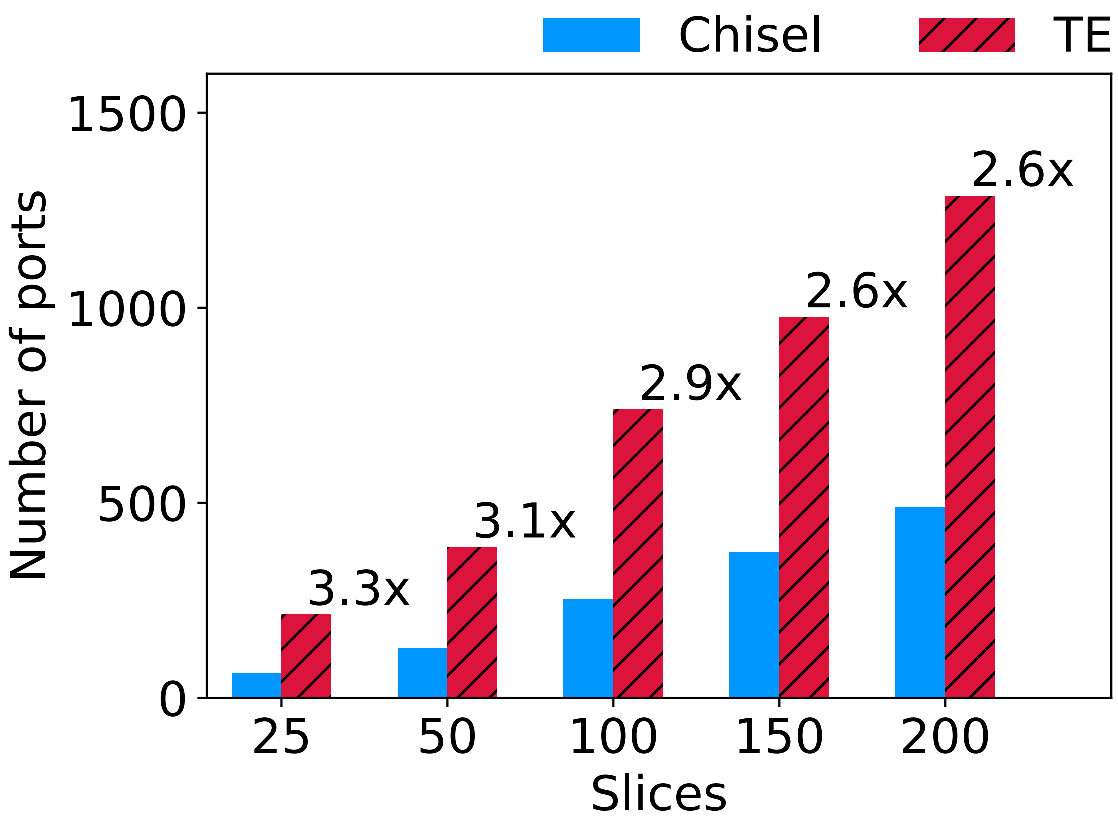


Network	IPv4, IPv6
Link	Transponders
Physical	Optics



- **Optical slices require fewer ports**
- **Minimal conversions**

Comparing CHISEL with TE



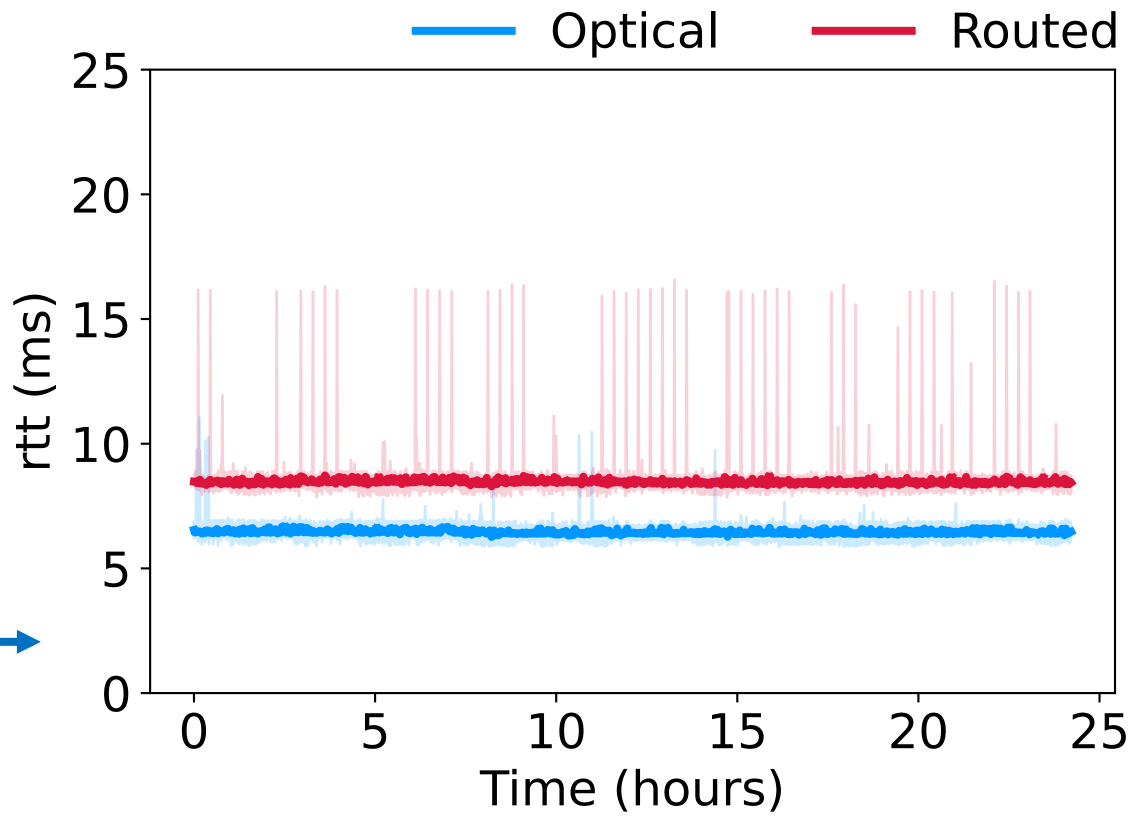
Chisel consumes up to 3x lower number of packet switched ports leading to cost savings.

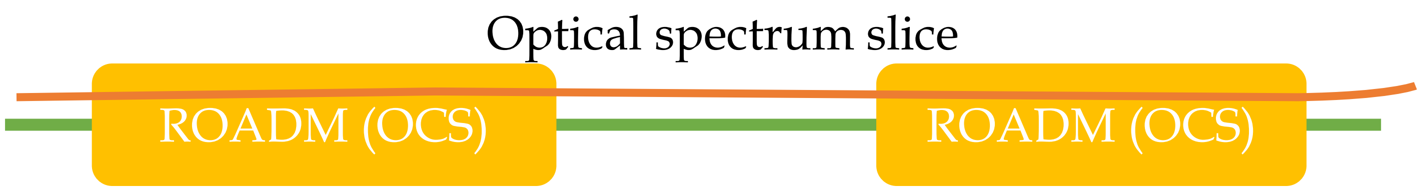
Chisel consumes ports only at the source and destination routers!

We should use optical slices with Chisel

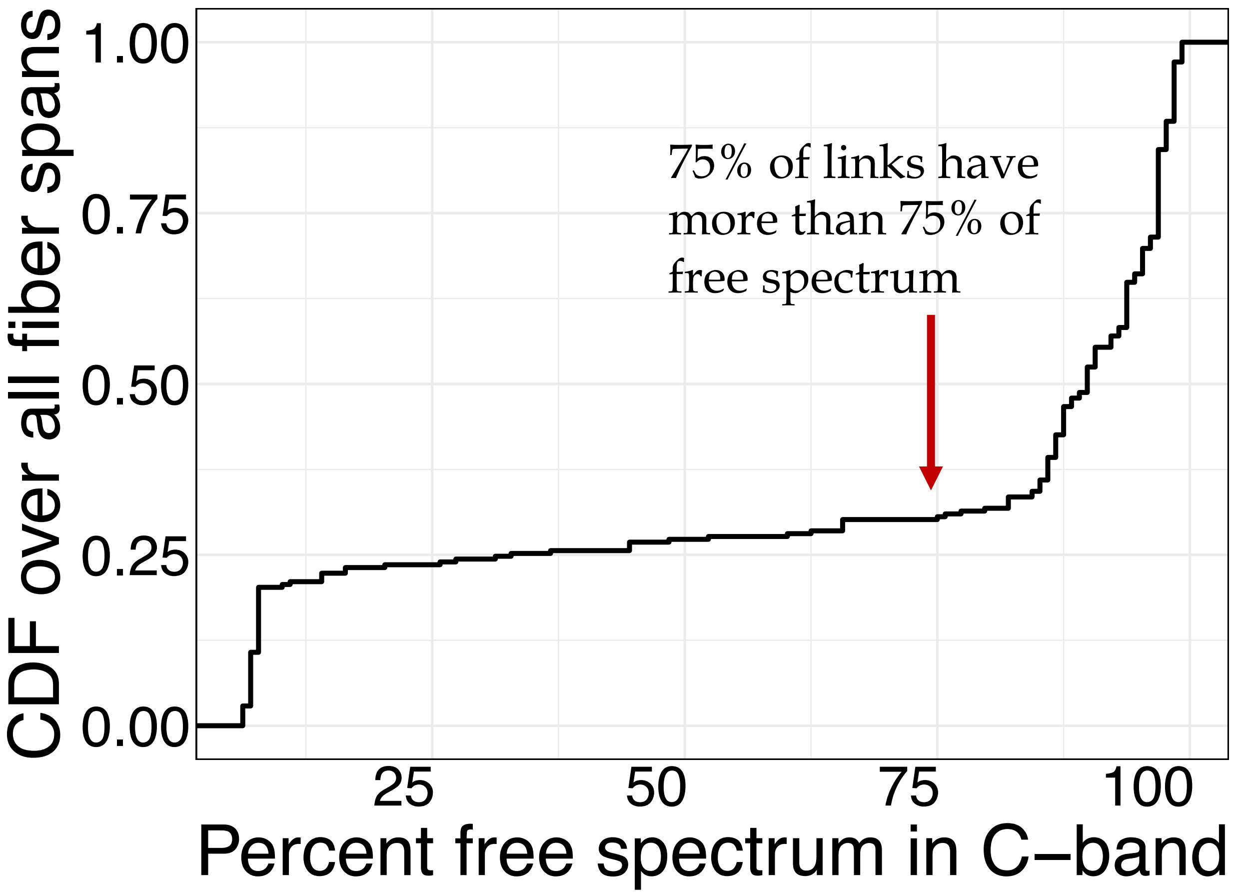
- Traffic engineered slices on packet switched routers
  - Limited number of priority queues
  - Incurs queueing delay

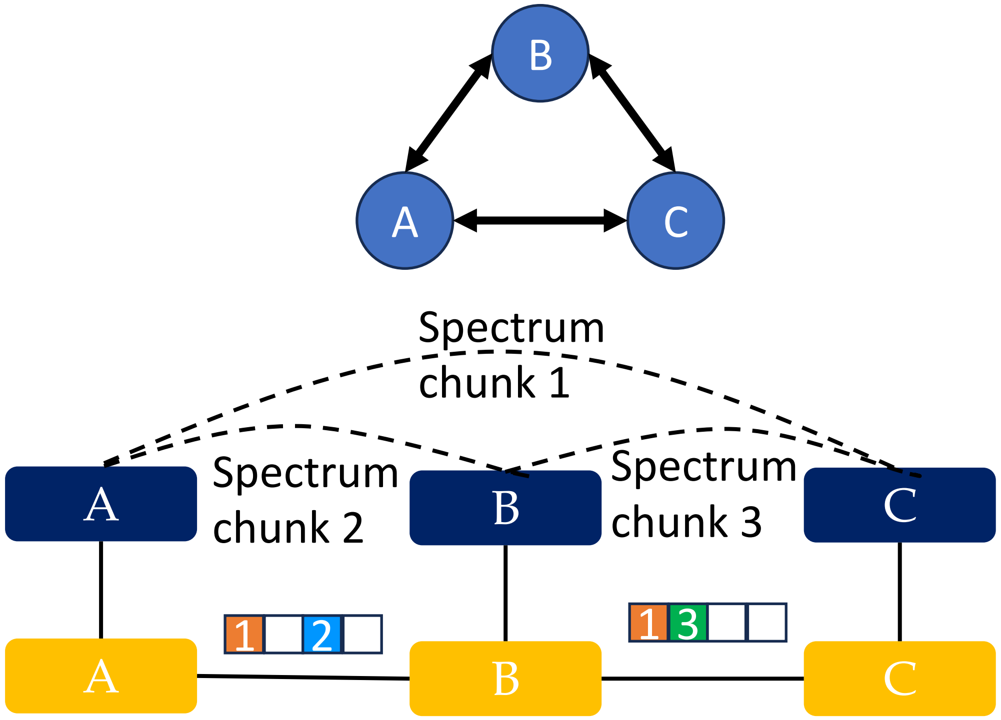
- Optical slices
  - Predictable and stable end-to-end performance





Optical layer has terabits of unused spectrum





- Optical paths are overprovisioned
- Spectrum is allocated incrementally

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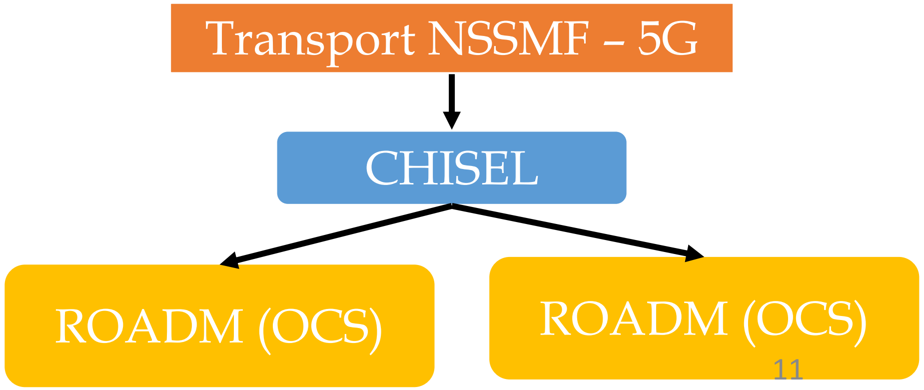
Challenges with optical slicing for 5G

- 5G bandwidth per device is 10-20 Gb/s
  - => 10s of devices can cause 100s of Gbps demand
- We need fast on-demand slicing

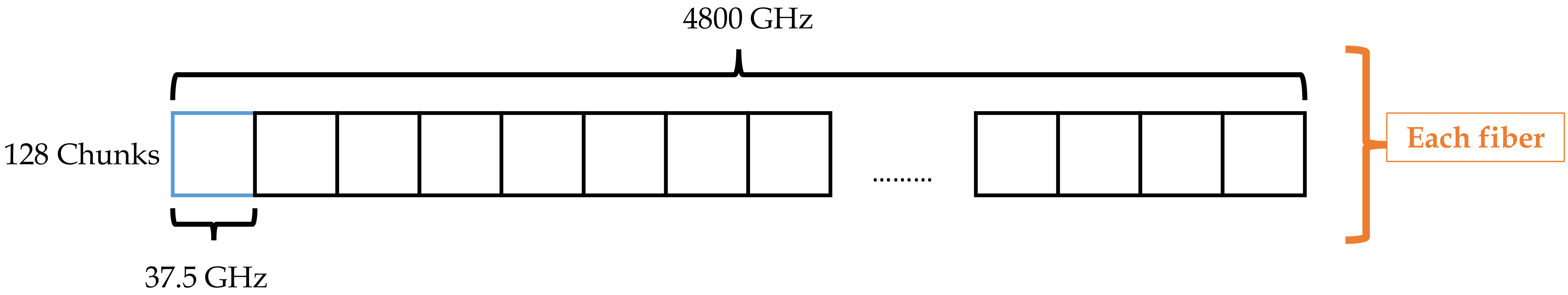
- Physical constraints
  - Fundamental to spectrum

- Implement it on hardware
  - Without disrupting existing wavelengths
  - Interface with legacy hardware



Allocating a single optical slice

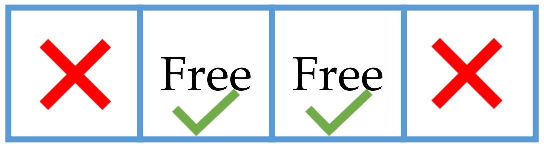
- Continuous optical spectrum is divided into chunks - Wavelengths



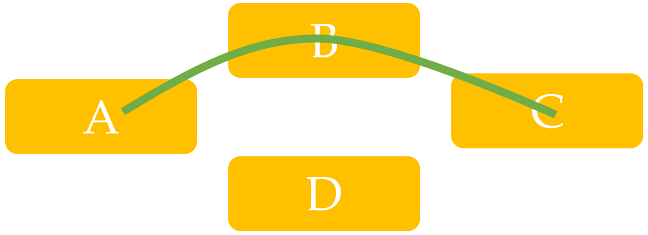
Modulation	Bandwidth	Reach
QPSK	100 Gbps	5000 Km
8-QAM	150 Gbps	2500 Km
16-QAM	200 Gbps	800 Km

Optimal and rapid on-demand optical slicing

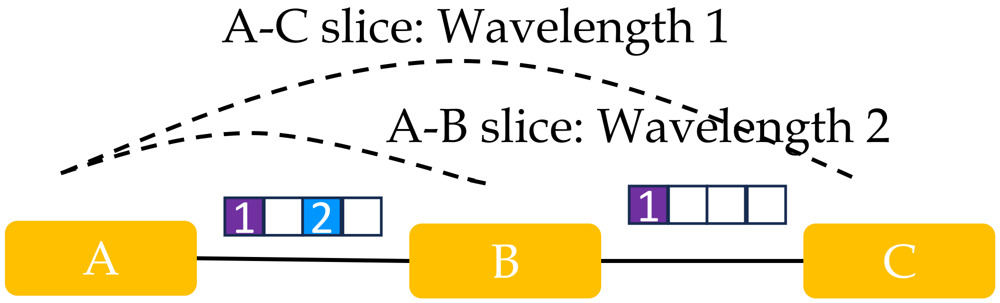
- We formulate the optimization as a MILP -- dynamically invoked



We allocate only free wavelengths to slices



Only one path per slice



No re-use of wavelength across slices on the same link

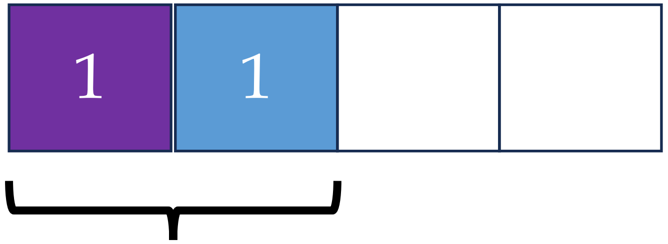
Wavelength continuity

Wavelength contiguity

Algorithm - overview

- Goal: Maximize the allocated bandwidth across all slices

Objective: Encode the goal



width or w_{sd} = sum(x_{sd}) = 2

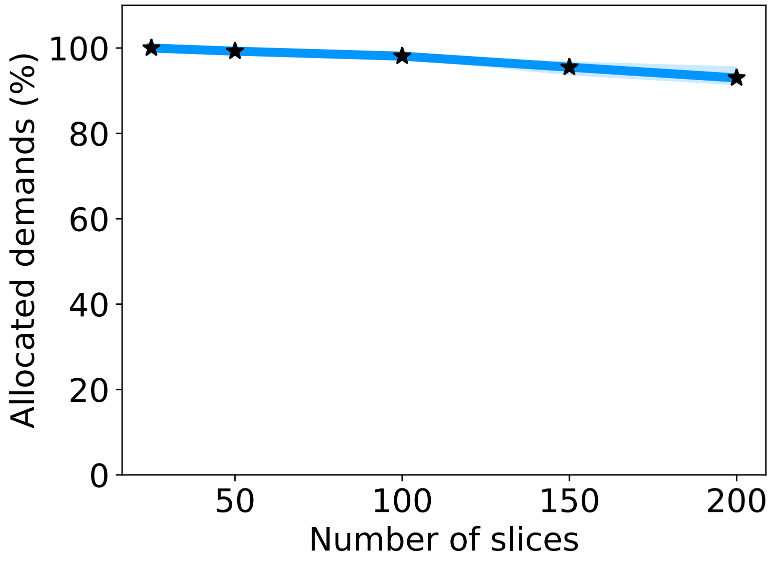
bandwidth = $w_{sd} * mod(p)$

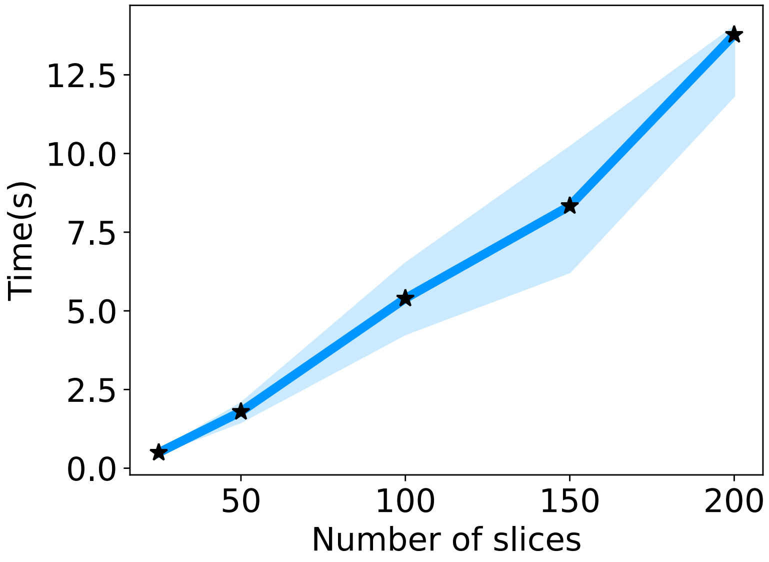
- Inputs:
  - G<V,E>: V switches, E fiber links
  - S^v : Initial spectrum on switch v
  - P_{sd}: Paths between s, d
  - B_{sd}: Bandwidth request

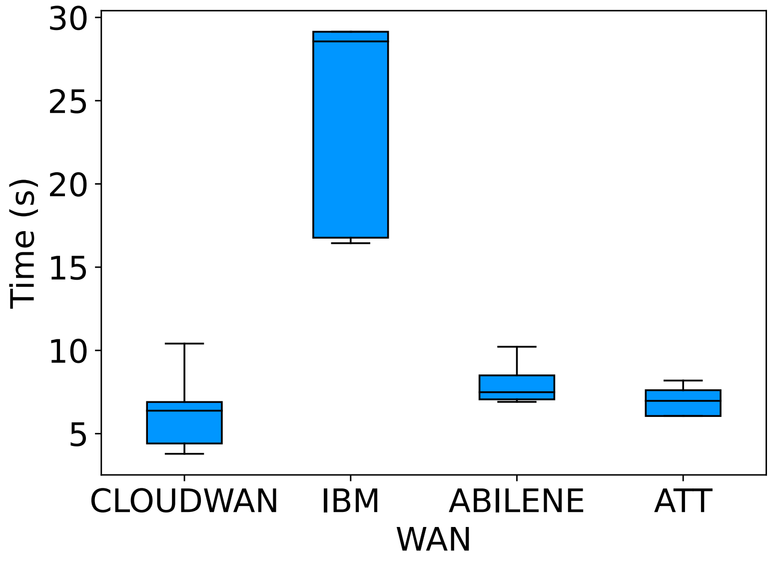
$$\textit{Maximize} \quad \Sigma_{sd}\, \Sigma_{p\epsilon P} y^p{}_{sd} * (bandwidth)$$

- Outputs:
  - $y^p{}_{sd}$: 1 if slice s,d is on path p
  - x_{sd}: s,d slice's spectrum bitmap ← **Obviate continuity constraint**

Algorithmic results – successful allocations



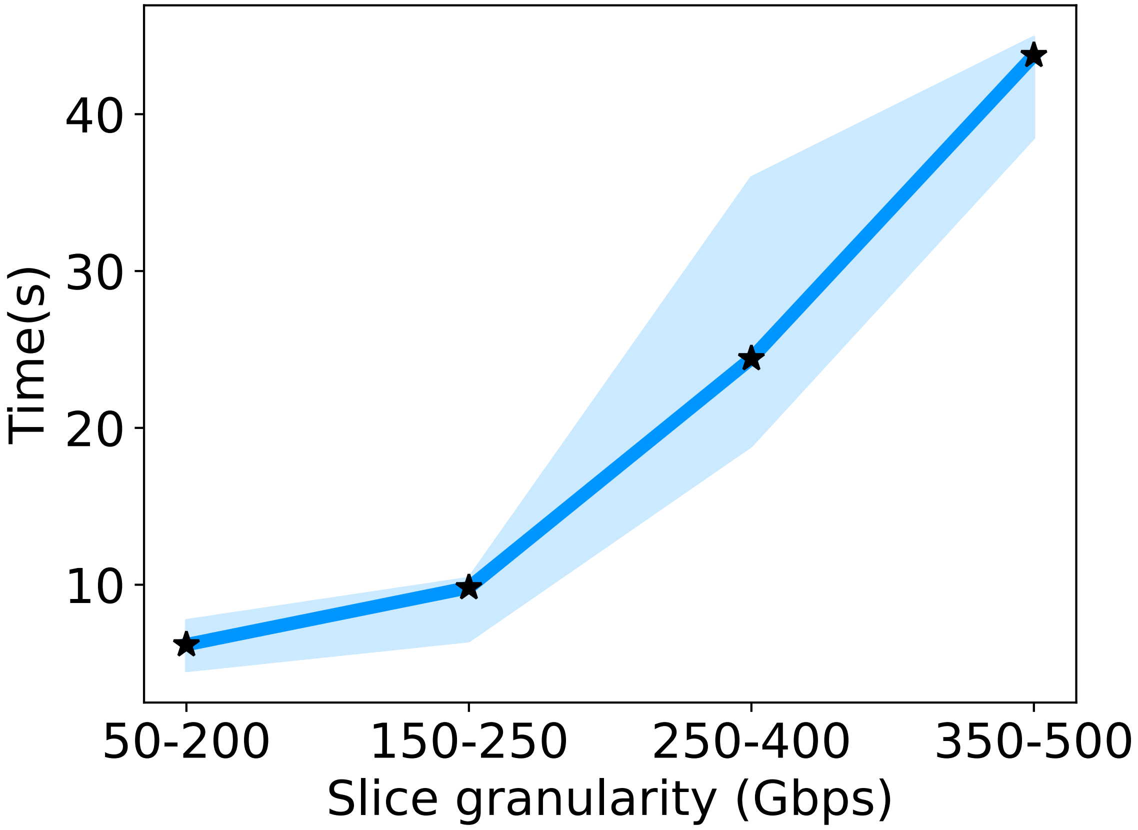




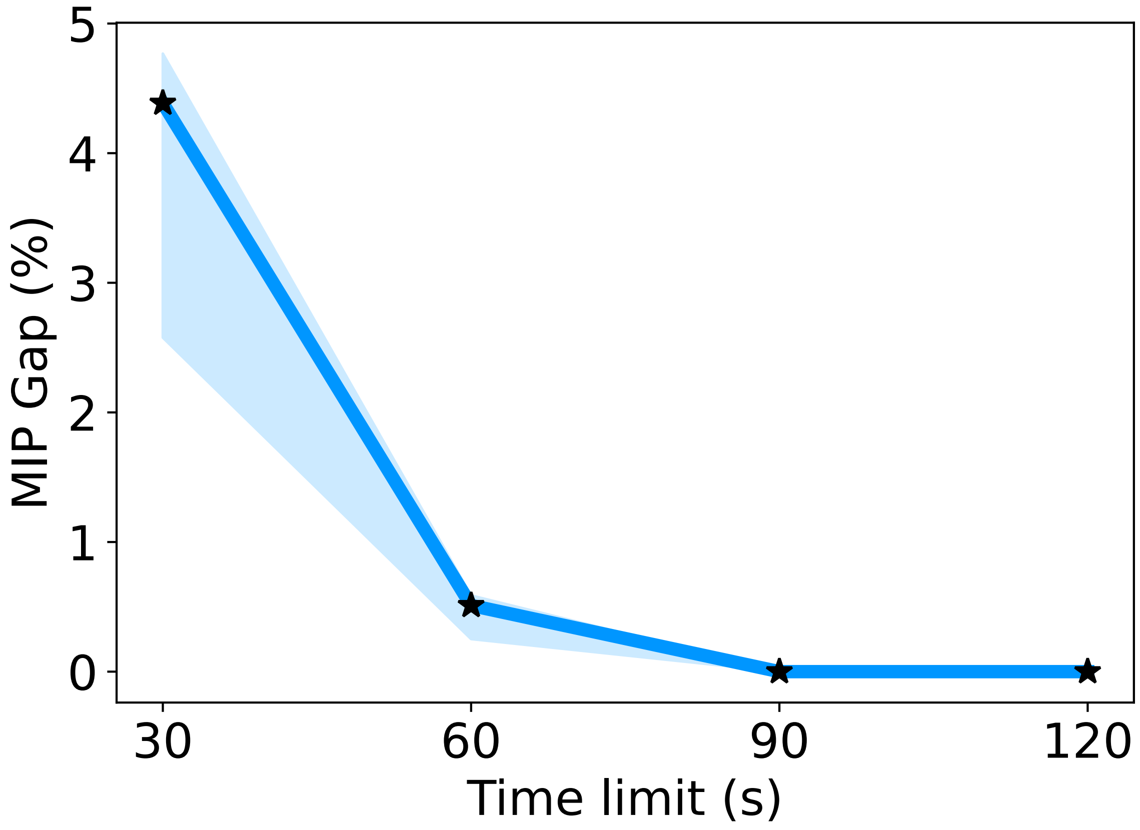
Scales to 100s of slices while allocating more than 90% of the slices

Converges in less than 30s across multiple topologies and 100s of slices

Reducing convergence time



Larger granularity leads to higher convergence time

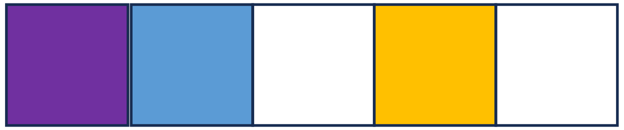


Larger granularity leads to higher convergence time

Future proofing the allocations

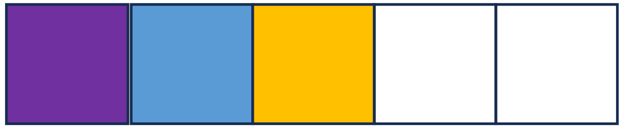
- Higher fragmentation leads to smaller contiguous chunks

Higher fragmentation

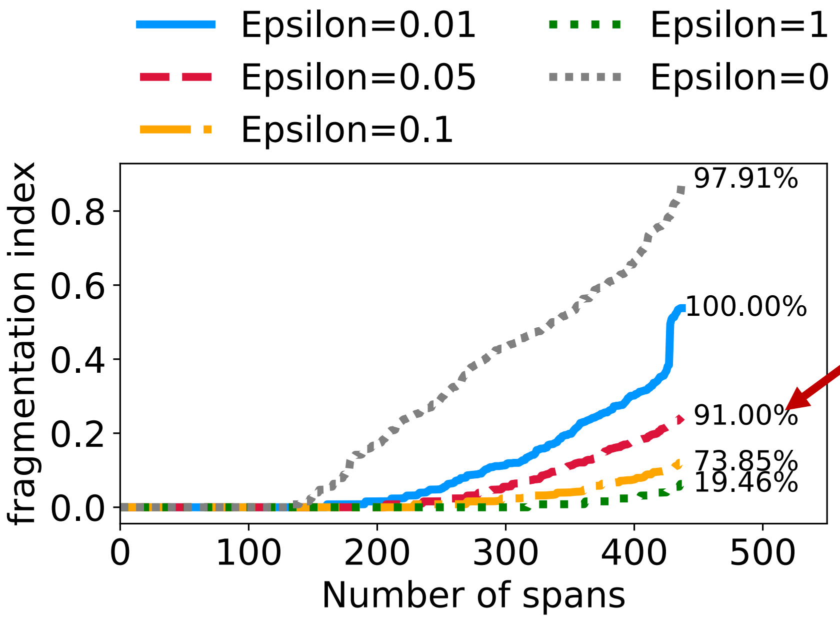


Allocation of a slice of 2 wavelengths fails

Lower fragmentation



Allocation succeeds



Tradeoff: Very low epsilon value results in a high number of slice allocations and low fragmentation index.

Reduce fragmentation in the objective

max(sum(bw, for all slices)) **+ ε * max(sum(contiguous chunks))**

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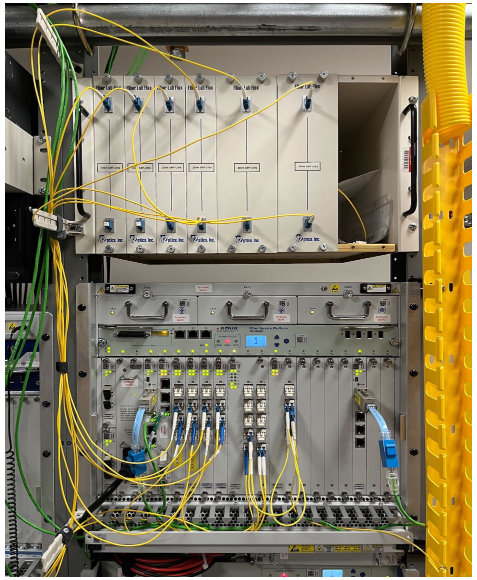
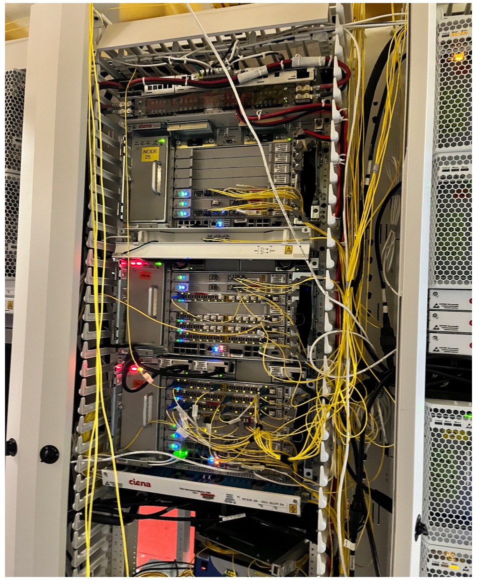
Hardware implementation

- Create the slices generated by CHISEL
- Program the ROADMs (OCSes)
- Test on two setups:
  - Lab testbed
  - Regional ISP WAN - Nysernet



ROADM in the field



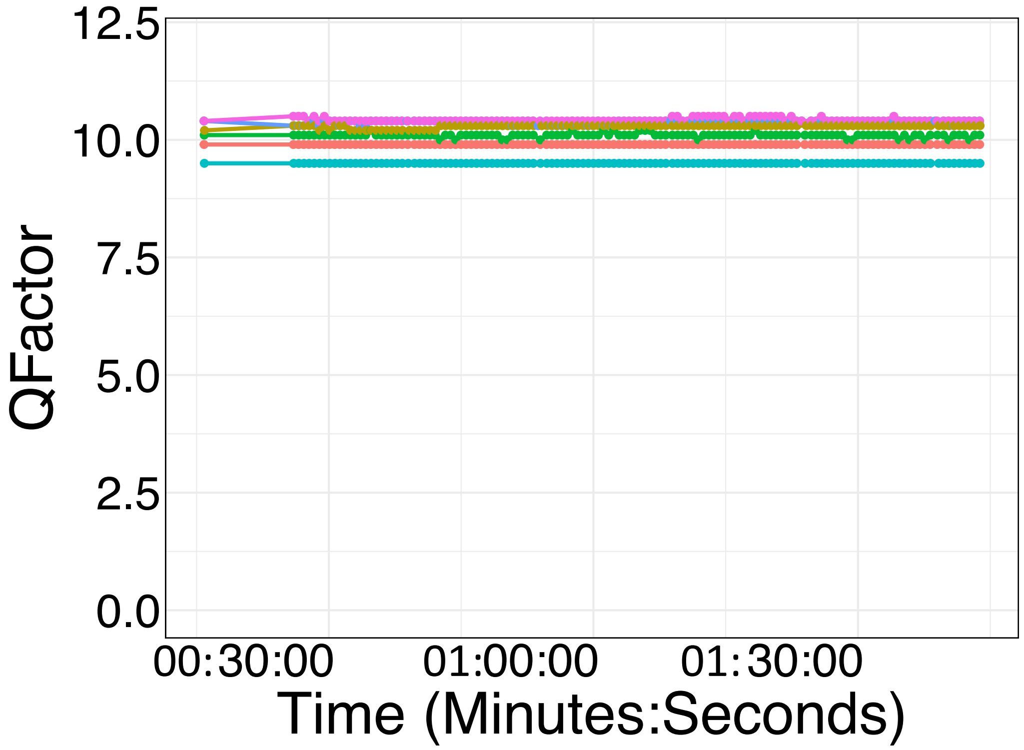
Topology in the lab

- Map router port to chunk 3
- Add chunk 3
- Route chunk 3 to B

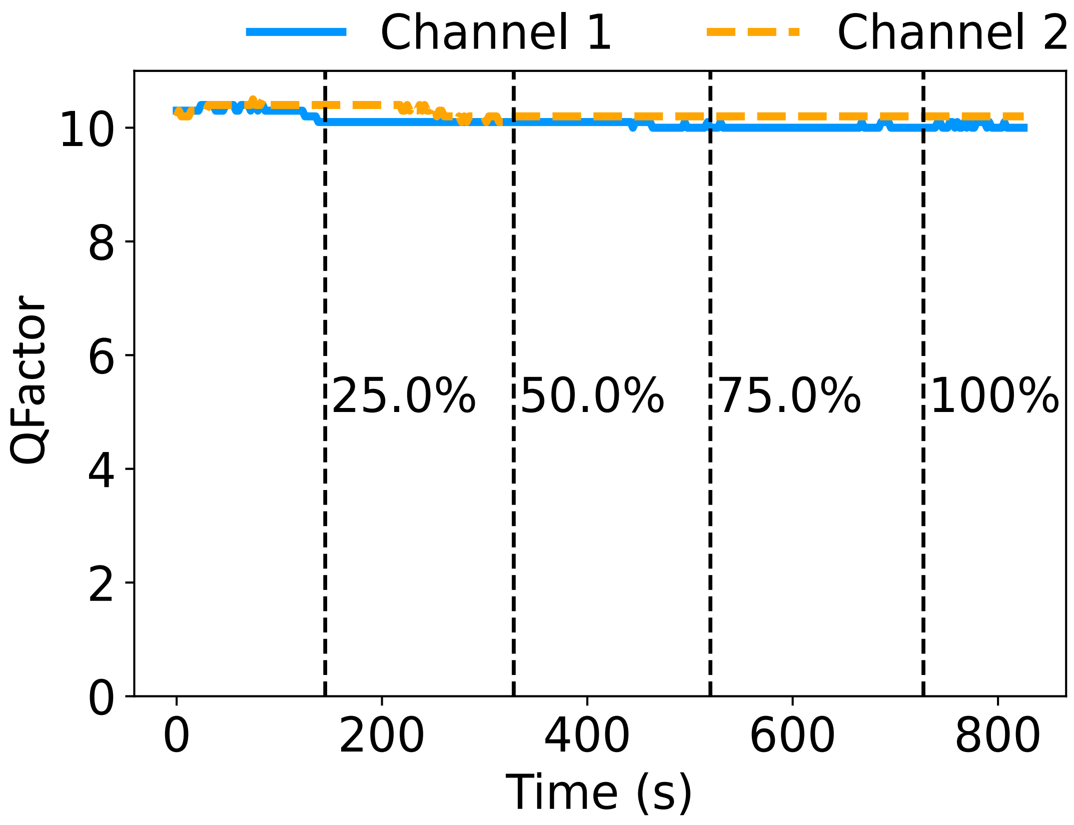
- Route chunk 3 to C

- Map router port to chunk 3
- Drop chunk 3

Impact on existing wavelengths



Existing traffic on educational WAN is not disrupted after adding 2 new wavelengths



Existing traffic on a single link is not disrupted after filling the spectrum on the link

Conclusion

- Chisel demonstrated the advantages of optical slicing.
- Chisel can quickly and dynamically allocate 100s of optical slices.
- Chisel’s output can be readily implemented on commodity hardware.
- **Chisel is open source**: https://opticalslice.network