The paper is available at https://dl.acm.org/doi/10.1145/3230543.3230570. Slides based on those from Rachee Singh. Thanks a lot!
Achieving High Utilization with Software-Driven WAN
[SIGCOMM ’13]

Calendaring for Wide Area Networks
[SIGCOMM ’14]

Dynamic Pricing and Traffic Engineering for Timely Inter-Datacenter Transfers
[SIGCOMM ’16]

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Microsoft

O(100) datacenters
Dedicated Wide Area Network
Costs O(100) million dollars per year
O(100,000 miles) of fiber
O(1,000) optical devices
Fiber is scarce, expensive

Identify inefficiencies in the optical backbone to gain capacity, availability at reduced cost.
Gain 134 Tbps of capacity and prevent 25% link failures in large North American WAN.
Outline

- How inefficient are optical backbones?
- Dynamic capacity links in WANs
- Challenges in dynamically adapting link capacities
- Rate Adaptive WANs
**Optical Backbone Networks**

- **Optical cross-connects (OXC):** switches optical signals

- **Signal-to-noise ratio (SNR):** measures signal quality
  - At OXC, measure signal quality
    - 8,000 wavelengths
    - Every 15 minutes
    - February 2015 to June 2017
Longitudinal Signal Quality on Fiber

Higher is better

Capacity Threshold
200 Gbps
175 Gbps
150 Gbps
125 Gbps
100 Gbps
75 Gbps
50 Gbps

RADWAN: Rate Adaptive Wide Area Network
Opportunity for capacity gain

For 8,000 wavelengths in WAN:

- Analyze average SNR
- Compare with thresholds for link capacity

64% of optical wavelengths can operate at 175 Gbps

95% of optical wavelengths can operate at higher than 100 Gbps

RADWAN: Rate Adaptive Wide Area Network
Opportunity for availability gain

• Distribution of link failure SNR
  • Across WAN links
  • For 2.5 years

25% of failures have SNR > 2.5dB

These failures can be prevented by reducing link capacity to 50 Gbps
Our proposal

- Dynamically adapt link capacities in response to changes in SNR.

**Gain 134 Tbps capacity**
- By increasing link capacity when high SNR

**Prevent 25% link failures**
- By reducing link capacity when low SNR
Outline

• How inefficient are optical backbones?
• Dynamic capacity links in WANs
• Challenges in dynamically adapting link capacities
• Rate Adaptive WANs
Challenges in dynamically adapting link capacities

• Requires hardware support for capacity reconfiguration

• Requires re-thinking IP layer traffic engineering
Hardware support for capacity reconfiguration

Small scale lab experiments show:

- Commodity hardware takes over 1 minute of link downtime to change capacity
- Able to reduce to 35ms with evaluation board
How should traffic engineering incorporate dynamic capacity links?

Capacity changes cause links to be unavailable for carrying traffic.

Capacity changes lead to network churn and can be disruptive.
Outline

• How inefficient are optical backbones?
• Dynamic capacity links in WANs
• Challenges in dynamically adapting link capacities
• Rate Adaptive WANs
We design a Rate Adaptive Wide Area Network (RADWAN) traffic engineering controller.

Solution

- **SNR-aware**
  - Knows possible capacity gain of each link

- **Rate Adaptive**
  - Adapts link rates to meet demands and improve availability

- **Minimally disruptive**
  - Reconfigure capacity while minimizing network churn
RADWAN Traffic Engineering Formulation

Inputs
- Network Topology
- Demand Matrix
- Optical Topology and SNR
- Current Flow Allocation

Optimization Objectives
- Constraints

Outputs
- Flow Allocations
- Links to reconfigure
Proof of concept: RADWAN

RADWAN: Rate Adaptive Wide Area Network
Throughput Gains with RADWAN

RADWAN has 40% Higher network throughput compared to SWAN

RADWAN: Rate Adaptive Wide Area Network

RADWAN has 40% Higher network throughput compared to SWAN
Conclusion

• Physical layer today is configured statically

• We show that this leaves money on the table, in terms of
  ◦ Network performance capacity
  ◦ Link availability
  ◦ Equipment cost ($/Gbps)

• **RADWAN** introduces programmability in Layer 1
  ◦ **Improves network throughput by 40%**
  ◦ **Reduces link downtime by a factor of 18**
  ◦ **Reduces equipment cost ($/Gbps) by 32%**
RADWAN
Rate Adaptive Wide Area Networks

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Manya Ghobadi / Microsoft Research
Klaus-T. Foerster / University of Vienna
Mark Filer / Microsoft Research
Phillipa Gill / U. Massachusetts Amherst
Interested in an Overview on Algorithmic Problems in Reconfigurable Networks?

**Toward Demand-Aware Networking: A Theory for Self-Adjusting Networks**
C. Avin, S. Schmid
ACM SIGCOMM Computer Communication Review, October 2018

**Survey of Reconfigurable Data Center Networks: Enablers, Algorithms, Complexity**
K.-T. Foerster, S. Schmid
ACM SIGACT News, June 2019