Are WANs Ready for Optical Topology Programming?

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Motivation: Network Agility via Programmability

- Demands on the network connectivity are growing
  - Requires the *network to be more agile and robust*
- In response, researchers have introduced *programmability* at different layers
  - Traffic Engineering (B4, SWAN, etc.)
  - Load Balancers (Ananta, Maglev, etc.)
  - Switches (P4, Sonic, Sonata)
  - Smart NICs
- Final frontier: programmable optical networks and their interactions with higher layers

Optical Topology Programming (OTP)

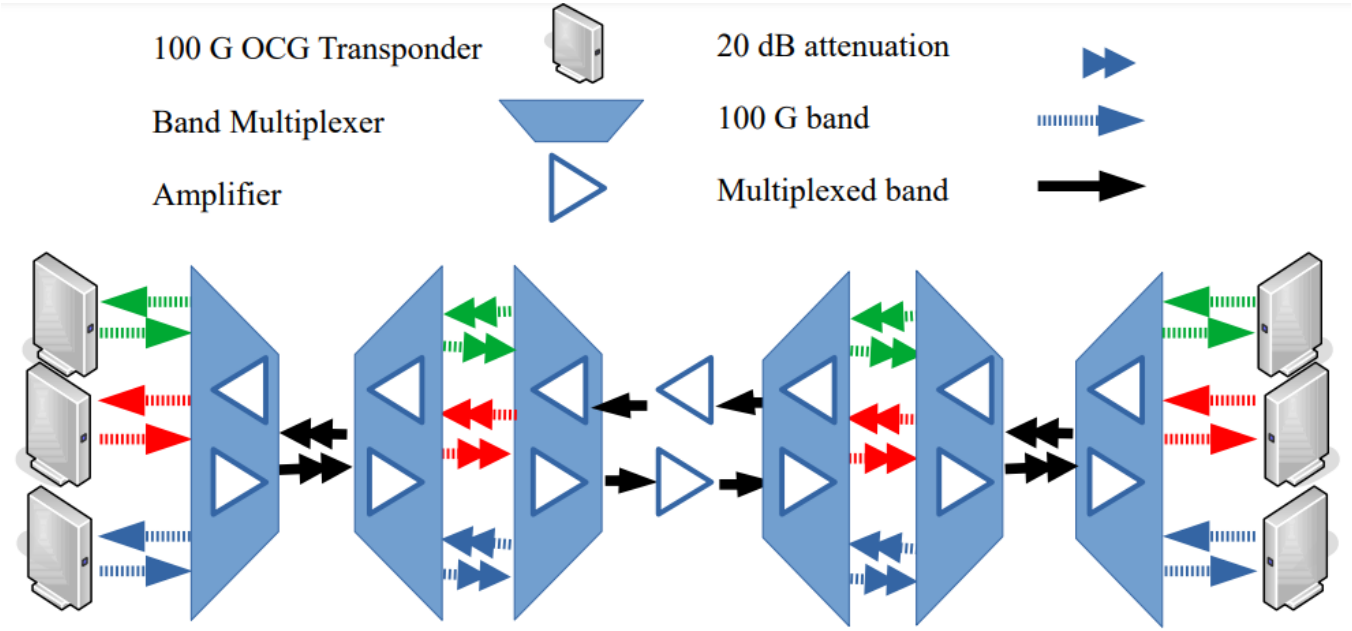
- The ability to *quickly* and *flexibly* reconfigure wavelengths on fiber paths in an optical network
  - Quickly: How much time is required to activate a long-haul wavelength?
  - Flexibly: What are the higher-layer interfaces for tapping into this capability?

Problem: Conflicting Perspectives on OTP WANs

- Evidence to support that optical layer is ready and capable
  - OWAN [SIGCOMM'16] – Uses reconfigurable links and is demonstrated on a to work on a testbed optical network
  - Moura et al. [JLT'16] – Cognitive Methodology for Optical Amplifier Gain Adjustment in dynamic DWDM Networks
- Evidence against
  - O-Net [OptSys'19], Optical-Packet Chasm [OptSys'20] – Research from both optical networks and networks systems can make unrealistic assumptions about the capabilities from the other layer
  - Methods for WAN link reconfiguration proposed nearly a decade ago still have no publicly-recorded implementations. E.g., [CORONET, JOCN'12]

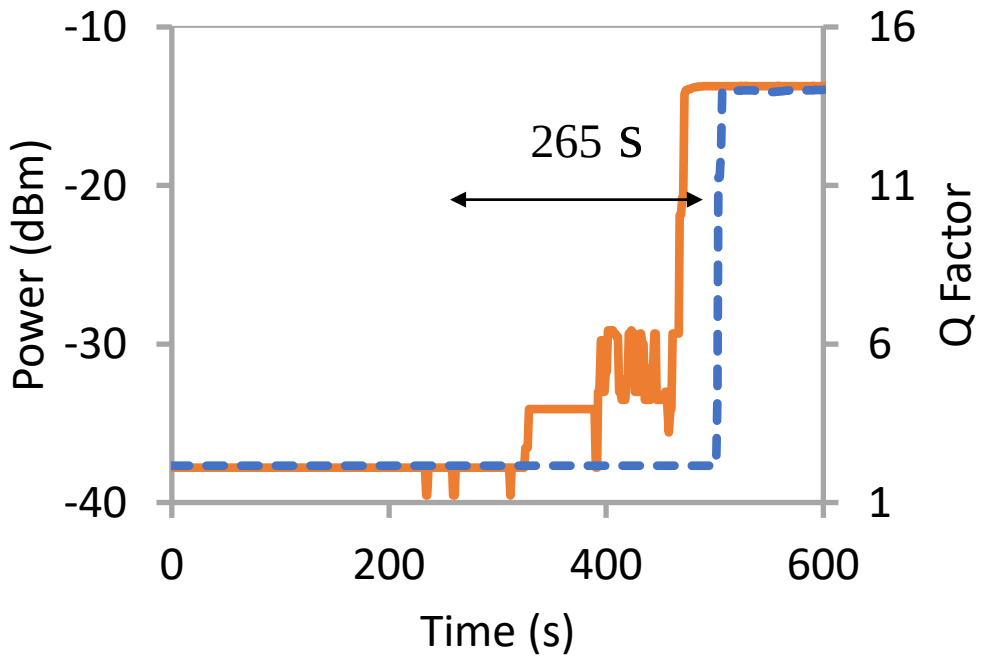
Resolving Conflict with Measurements

- Investigate the feasibility for OTP by measuring the time taken to stabilize an optical path
- Use equipment commonly provisioned in WAN networks



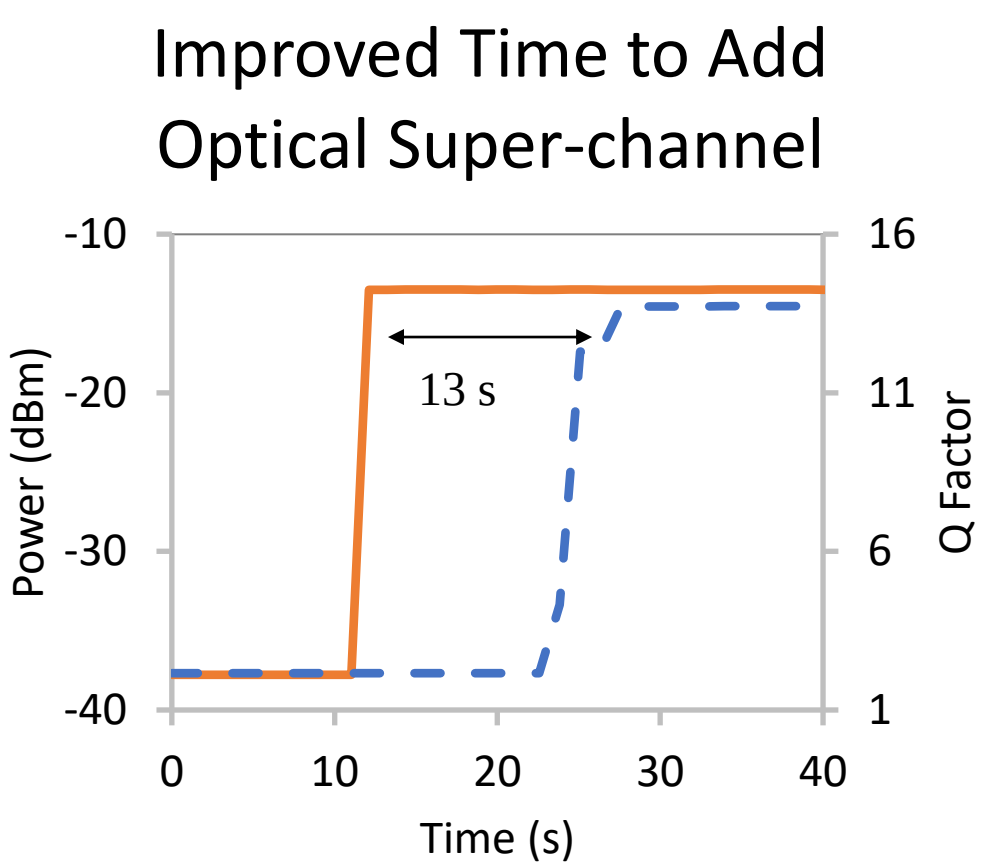
Baseline Measurements

Default Time to Add Optical Super-channel



- Total time from power-on until signal decoded is 265 seconds
  - Almost 5 minutes
- Evidence of power negotiation between source and in-line elements
  - Jagged solid line
- Key Takeaway: Removing the power negotiation step may significantly reduce provisioning time

Improvement Based on Configuration

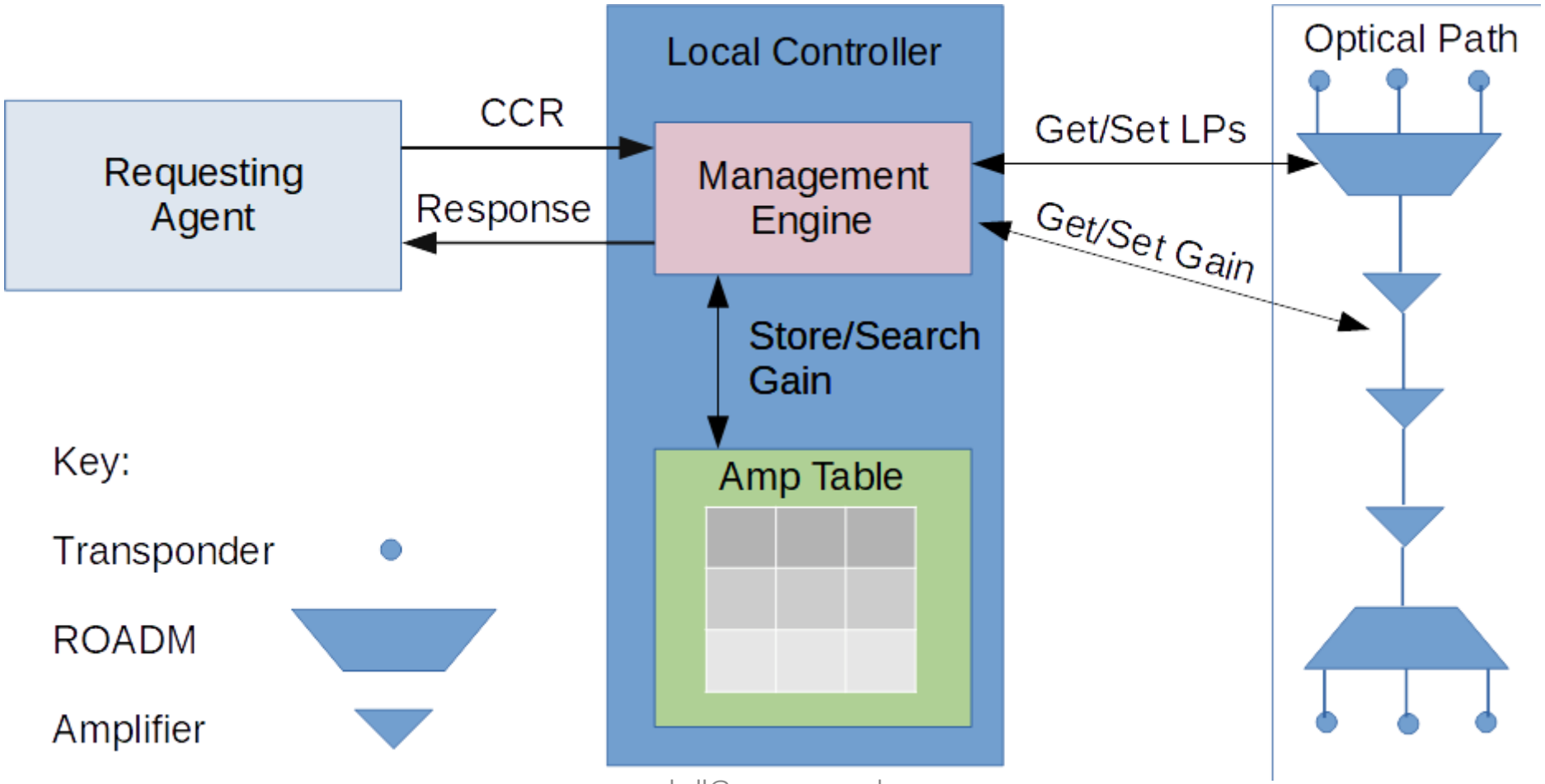


- By manually setting launch power the total time is reduced to 13 s
- Significant time where endpoints are not observing change
  - Amplifier-to-amplifier power management negotiations
  - Amplifiers had no manual interface for setting pump power level

Can We Do Better?

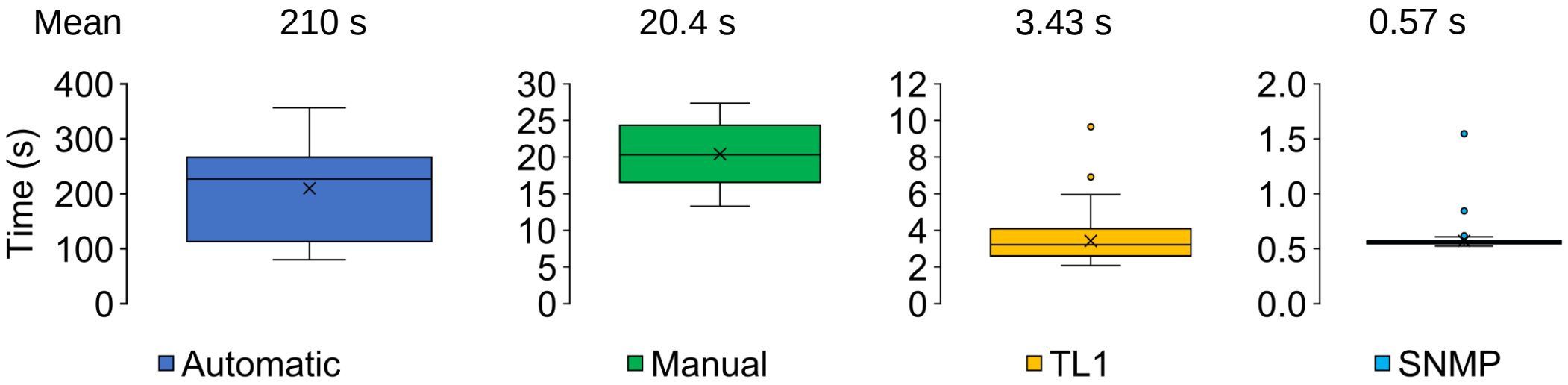
- May be able to intercede in the amplifier control loop to set the power level manually, similarly to how we did launch power for the transponders
- Two methods of remote interaction available for these amplifiers
  - TL1 and SNMP
- We compare the time to read the power level from each amplifier on the path with both TL1 and SNMP
- Compare this with the time to activate the circuit in automatic and manual modes

Amplifier Power Configuration Lookup Table



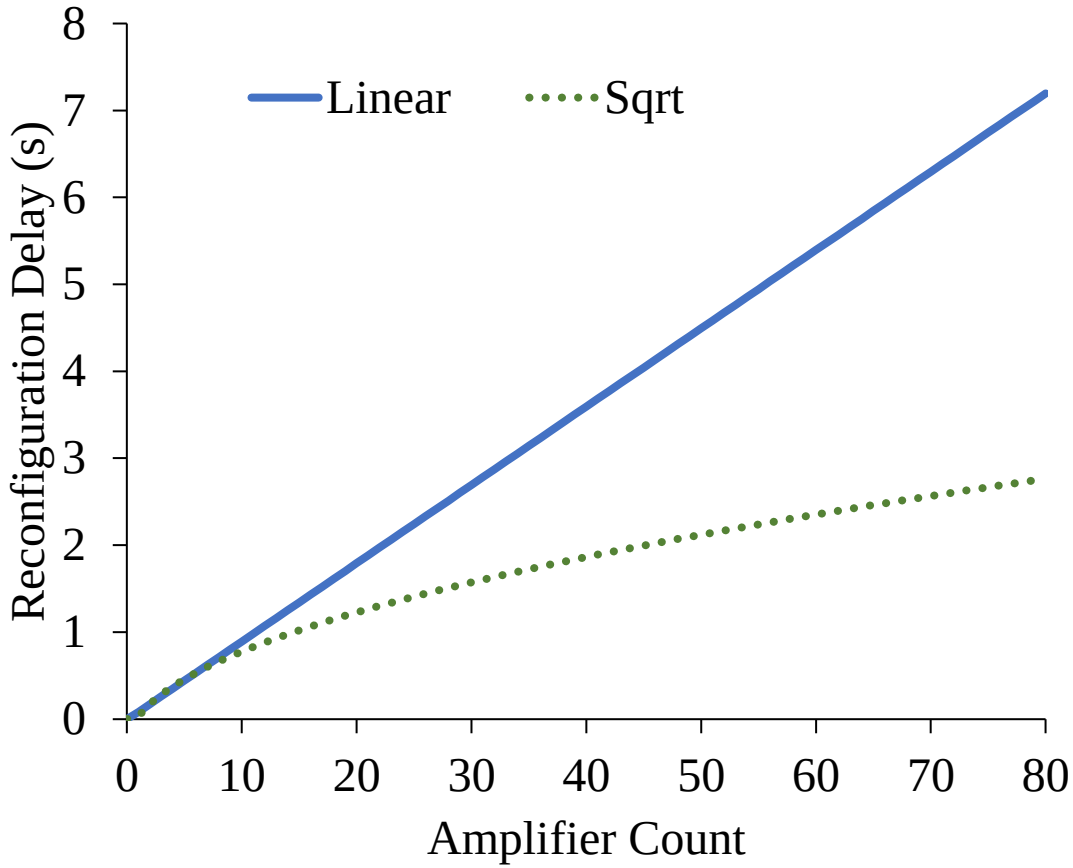
Comparison Results from Our Testbed

- Long-haul link reconfiguration today, for a 7-amplifier path, is roughly 20 to 210 seconds based on configuration settings
- If we could programmatically configure amplifiers on the path, we could reduce this time to the 0.57 to 3.43 second range



Projected Delay for Long-haul Paths

- How fast can reconfiguration be for continental and trans-oceanic paths?
- At least 80 amplifiers are expected for spans up to 6400 km long
- Regression model trained to fit a linear and square root curves suggests time from 2.5 to 8 seconds



Discussion and Work In Progress

- Empirical measurement efforts can inform critical gaps between optics and networking communities
- “Stable physical layer” model is at odds with “dynamic physical layer”
  - We showed evidence that the minutes-long reconfiguration delay is partially a relic of an outdated “stable physical layer” model
  - Now is the time to reconsider the physical layer assumptions implicit in network protocols and hardware
- Bringing OTP to the WAN calls for collaborative efforts
  - Enterprise and transit providers input is essential
  - Software hooks for controlling optical devices are necessary, and their implementations should preserve privacy and security restrictions inherent in backbone WAN networks