EXPERIMENTAL DEMONSTRATION OF ATTENUATION-BASED ALL-OPTICAL TIME-TO-LIVE INDICATOR

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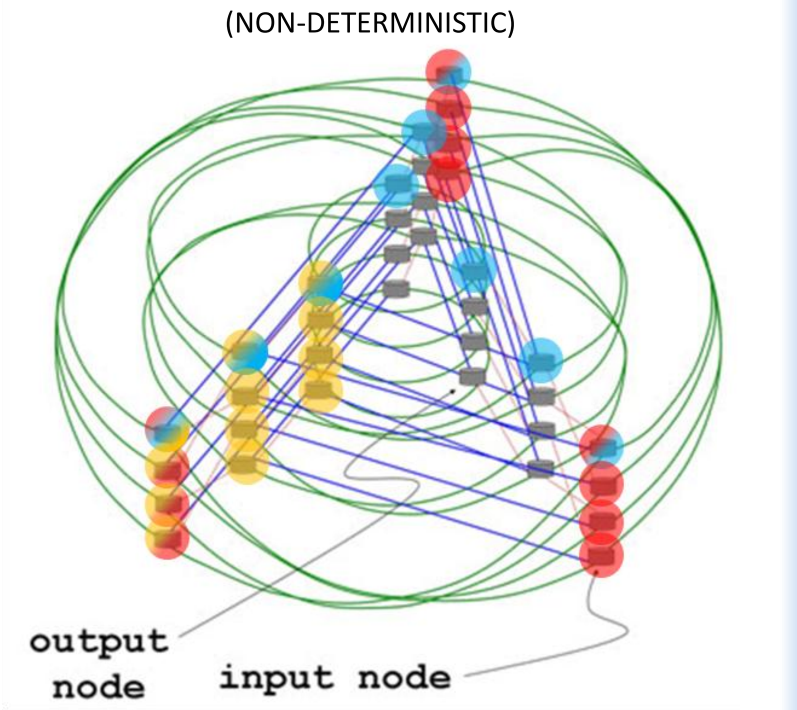
OPTICAL TIME TO LIVE (OTTL)

TIME TO LIVE

- A Mechanism To Limit Packet Lifespan In Network
  - Usually Implemented As A Counter In Packet Header
    - E.g. IPv4, IPv6
  - Counter Is Set To A Chosen Maximum By The Source
  - Each Network Switch Must Reduce Count Towards Zero
  - When Count Is Zero, Packet Is Dropped From Network
- Benefits To Optical Networks
  - Discard Undeliverable Packets (e.g. Unreachable Address)
  - Discard Corrupted Packets (e.g. Low Packet OSNR)

DATA VORTEX OPTICAL NETWORK

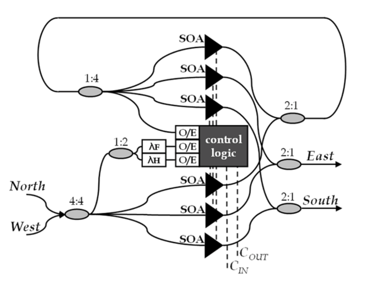
(NON-DETERMINISTIC)



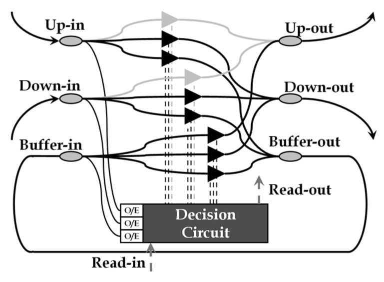
ALTERNATE OTTL APPROACHES

- Low-Speed MPLS-like Optical Label
  - Digitally Encode TTL Value in Low-Speed Optical Label
  - Each Switch Must Read & Rewrite TTL Count
  - Increased Switch Latency, Complexity & Cost
- OSNR Measurement
  - In-Band & Out-of-Band Techniques
  - Source Must Degrade OSNR to Set Lower TTL Limit
  - Power-Averaging Methods
    - Increased Switch Latency
  - BER Measurement
    - Receiver Sensitivity Requirements Scale With Data Rate
    - Increased Switch Latency & Cost

BUFFERED DV SWITCH



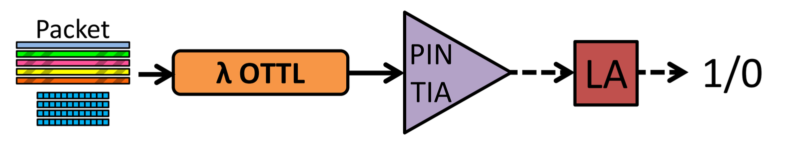
OPTICAL BUFFER



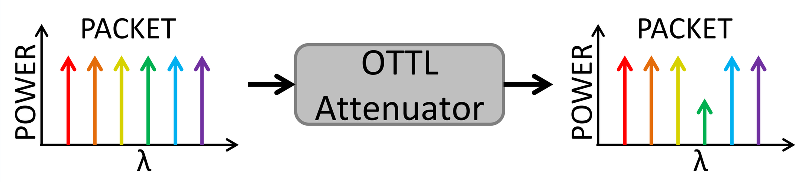
ATTENUATION-BASED OTTL

HOW IT WORKS

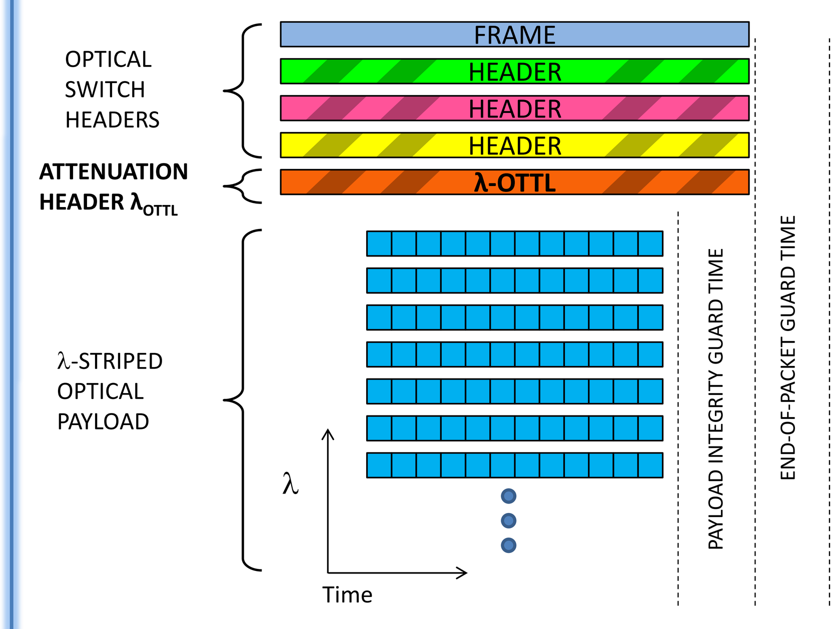
- Source Sets Initial Power In λ_{OTTL} To Define # Hops
- Each Switch Detects λ_{OTTL} As Any Other Header
  - Detected Binary Value Determines If Packet Dropped



- Each Switch Specifically Attenuates λ_{OTTL}
  - In Addition To Packet's Total Attenuation In Switch
  - Attenuator Ideally Does Not Affect Rest of Packet



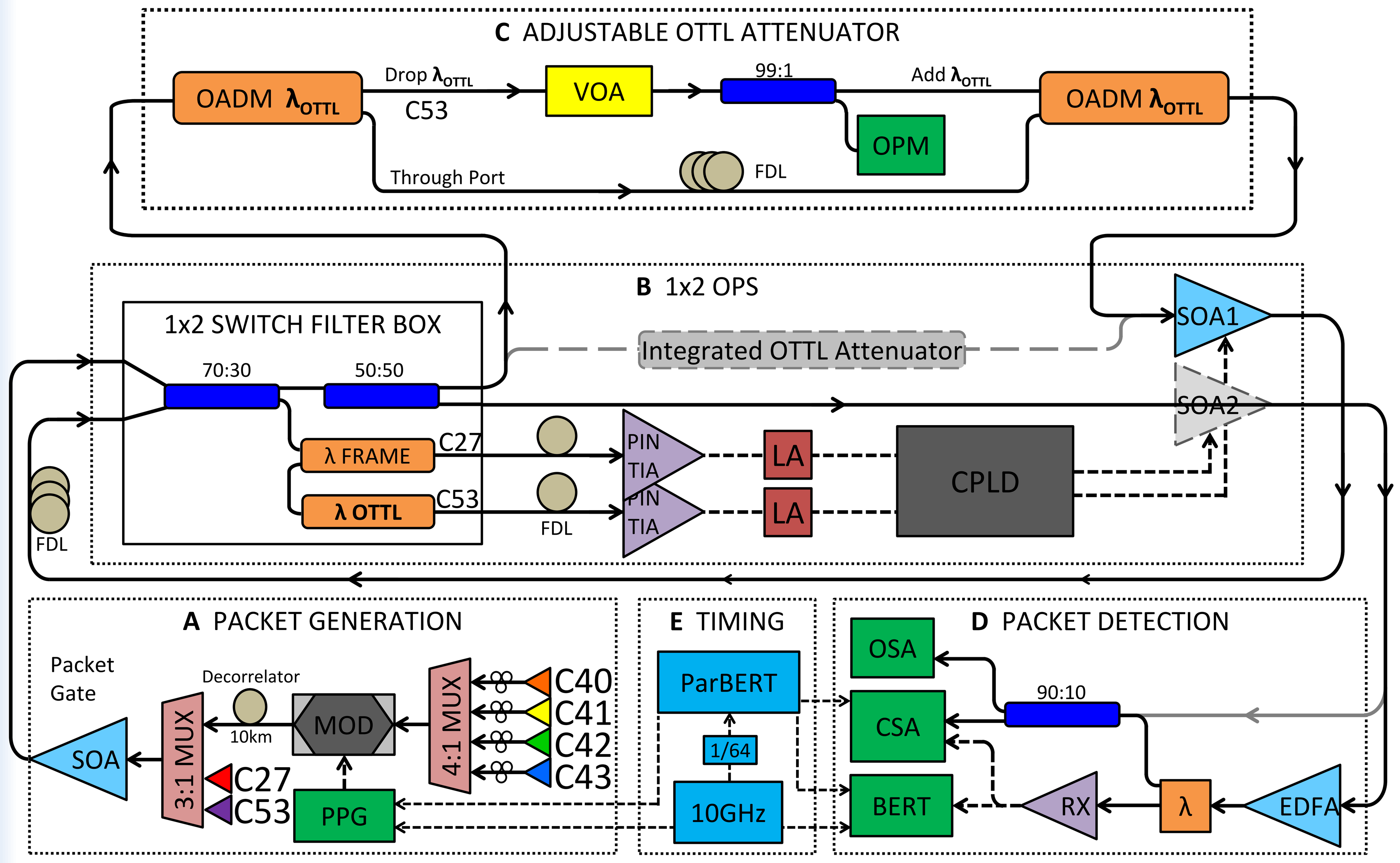
WAVELENGTH-STRIPED OPTICAL PACKET

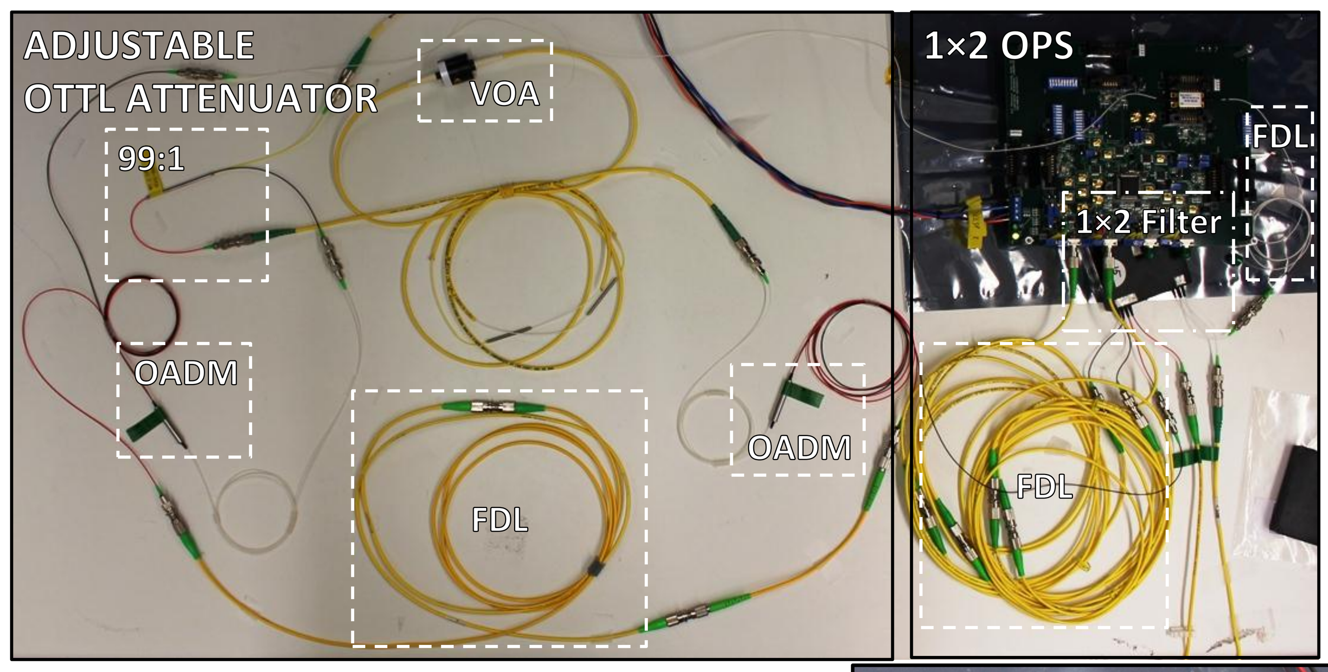


ADVANTAGES

- Low Latency Per Switch
  - Amplitude Measurement Occurs with Optical Header Detection
  - No Time-Averaging Necessary
  - Simple Binary Decision
  - No Complex Processing
- Low Complexity & Cost
  - Modified Gain-Flattening Thin-Film Filters
  - One Low-Speed RX
- OTTL Limit Can Be Independently Set
  - By Both Source & Switch Designs
  - No Need to Degrade Data To Set Maximum
- OTTL Can Be Arbitrarily Placed In Network
  - Placement is Not Necessary at Every Switch
  - E.g. One Every Other Stage of Buffered Butterfly

EXPERIMENTAL SETUP





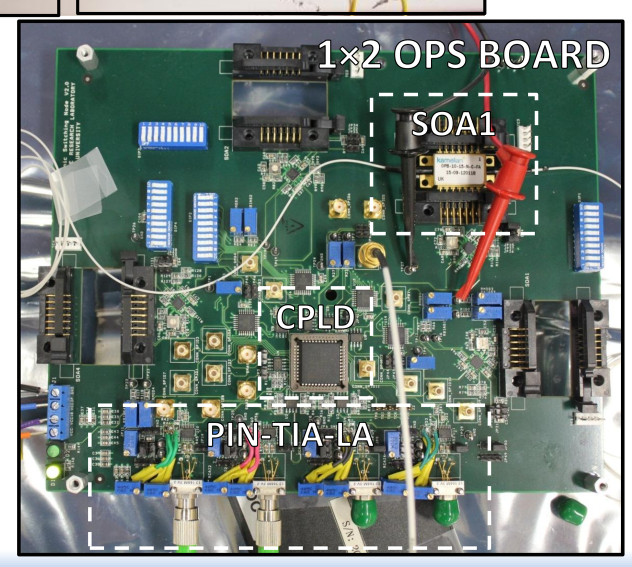
1-INPUT 1-OUTPUT OPTICAL BUFFER SETUP

A – Create λ-Striped Packet w/4 Payload Ch.

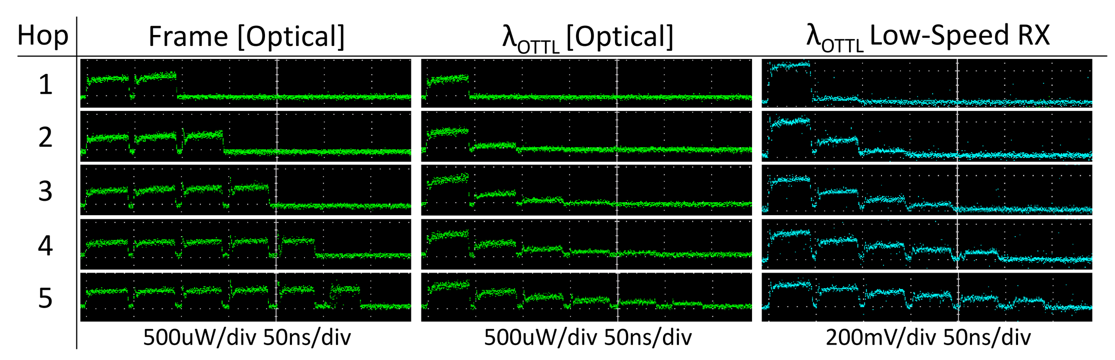
B – OPS Processes Packet Header
λ_{OTTL} Decision as 1 or 0
SOA1 or SOA2 Activated

C – Insert Attenuation Only On λ_{OTTL}

D – Observe Packet With Each Hop
Packet Dropped When λ_{OTTL} Below RX Threshold

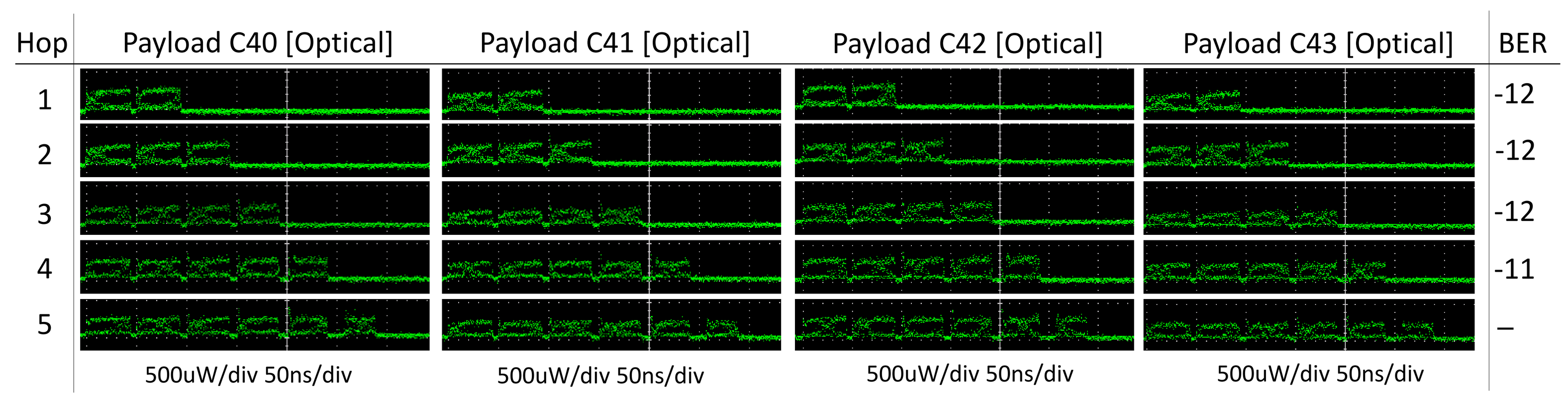


PACKET MEASUREMENTS



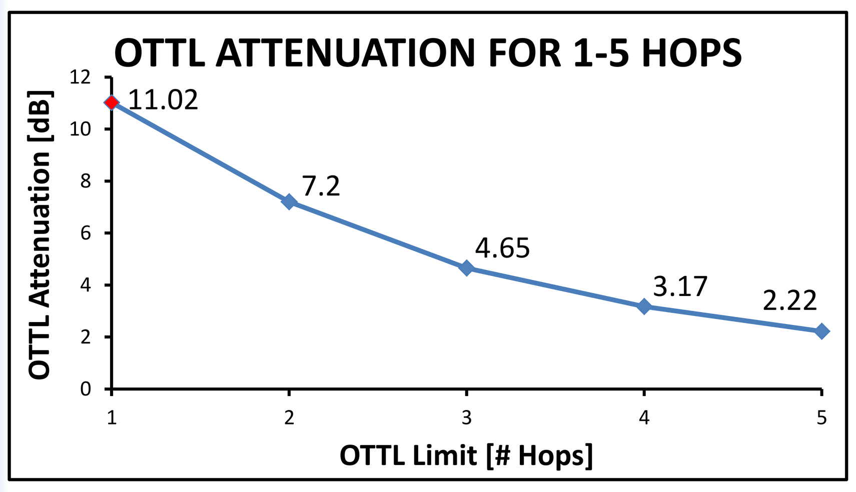
As Attenuation Is Reduced From λ_{OTTL},
The Optical Packet Travels More Hops Through The Buffer

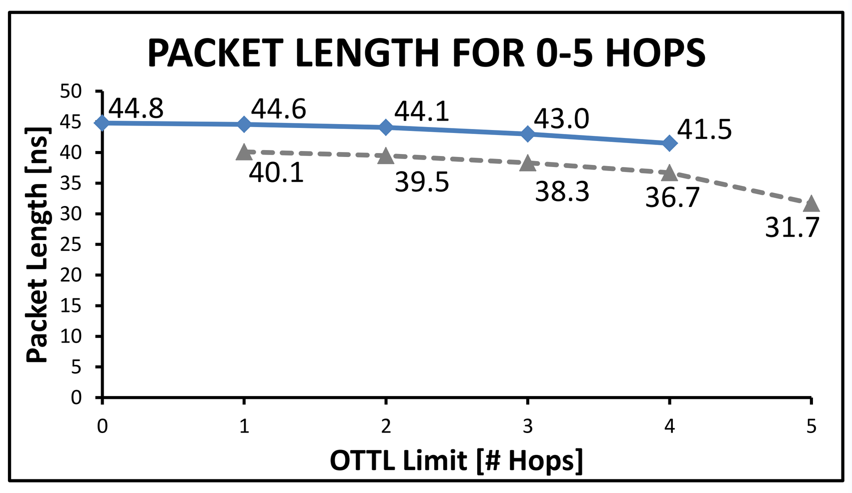
Both The CSA's and The Switch's Optical Receivers Show Simultaneous Loss of λ_{OTTL}



All Four Payloads Received Error-Free At 10^{-12} For OTTL Limits Of 1, 2, & 3 Hops

OTTL ATTENUATION





Required Attenuation Appears to Follow An Exponential Decay Curve

Packet Length Reduction Occurs Due To The Finite Rise & Fall Time Of The SOA

CONCLUSION

A novel method was shown to provide an Optical Time-To-Live capability for wavelength-striped optical packets based on cumulative attenuation of a selected wavelength. This method offers low latency and potentially low component investment, and offers straight-forward integration into wavelength-striped OPS designs. This method can be engineered for a specific maximum OTTL limit, while allowing the packet source to reduce this limit on the fly. This demonstration was achieved with little optimization of the setup, which suggests the maximum error-free OTTL limit can be further increased. Lastly, as OPS components and designs approach the ideal switch behavior (e.g. wavelength-flattened low insertion loss, low noise, low optical switch ringing, Schmitt-triggered receivers) this method's capability as an OTTL indicator improves.

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