Computer Visualization of Optical Network Behavior

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Introduction

Today's optical communication networks are based on wavelength-division multiplexing (WDM), in which multiple wavelengths of signals are transported in each fiber. The network topology is mesh, in which multiple fibers intersect at a node and WDM signals are switched at each node to the proper destination through the Generalized Multi-protocol Label Switching (GMPLS) management model. The GMPLS management model uses a set of control parameters to optimize the processes to yield the most efficient operation of the network.

Purpose

The methods to intelligently optimize network resource allocation are an important research topic in optical network management. The network research is to study and identify the proper management model and control parameters.

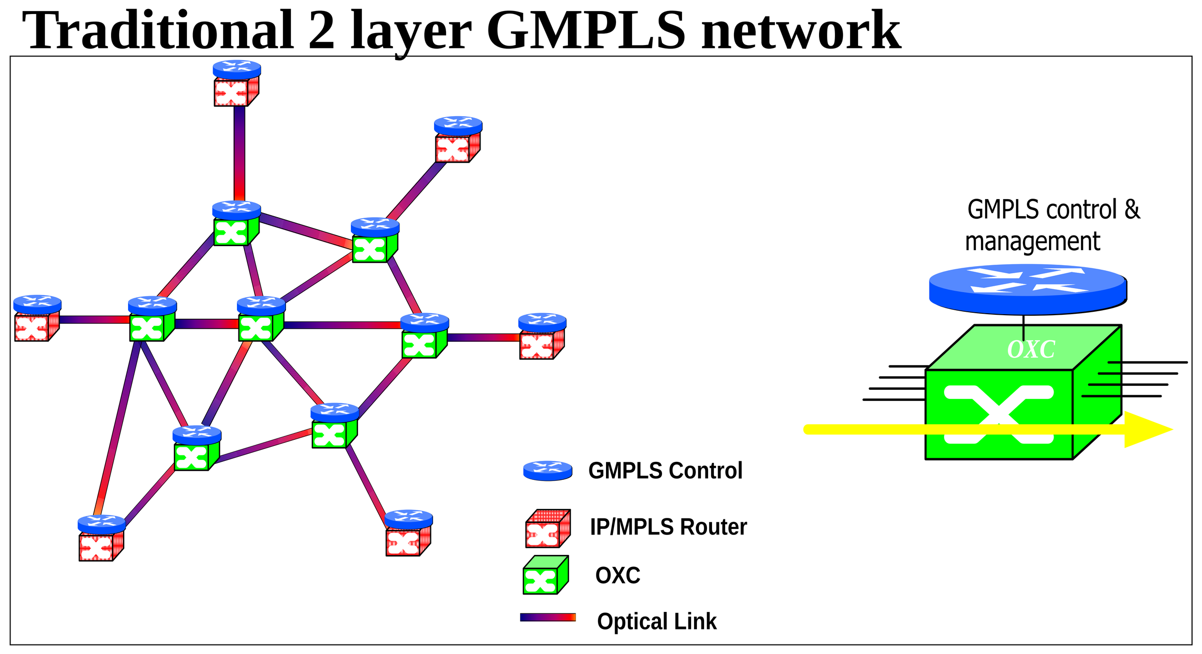
My research involves the designing and coding of a visualization application that will be utilized to examine optical network behaviors under different management approaches.

Network Challenge

Traditional network management research approaches only look at the final network performance matrices (throughput, blocking probability, etc.) without close examination about how the network components are performing under traffic engineering schemes. The intention of the visualization program is to show dynamically how traffic is distributed and travelling through the network. It will provide much insight on how the control parameters perform and can suggest how to adjust the parameters to achieve improved traffic engineering.

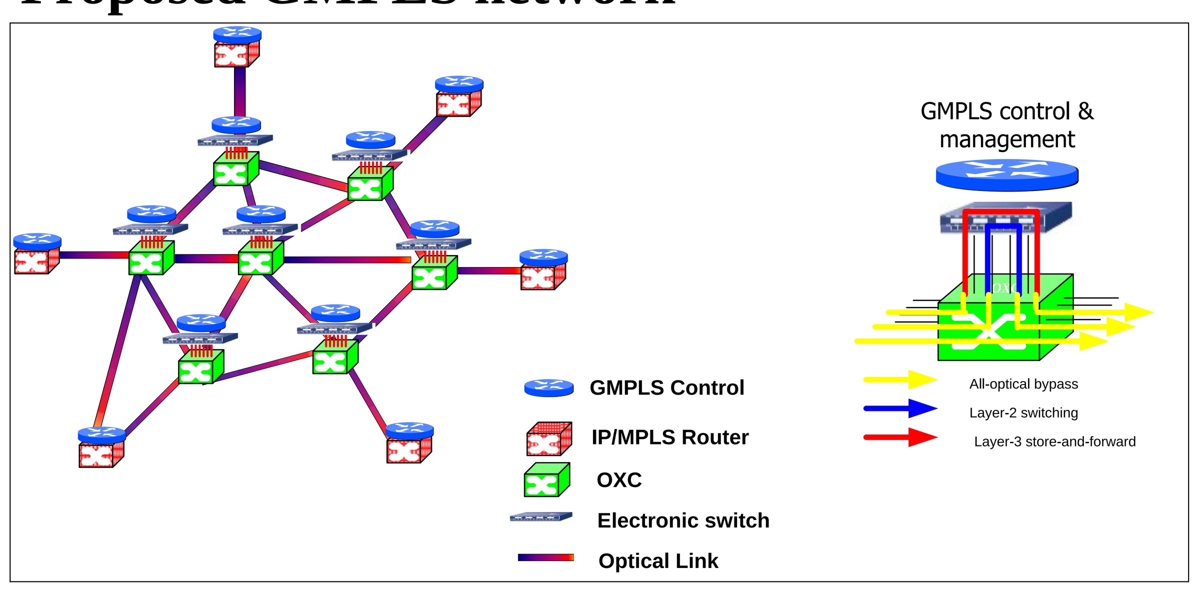
Network Model Architecture

Traditional 2 layer GMPLS network



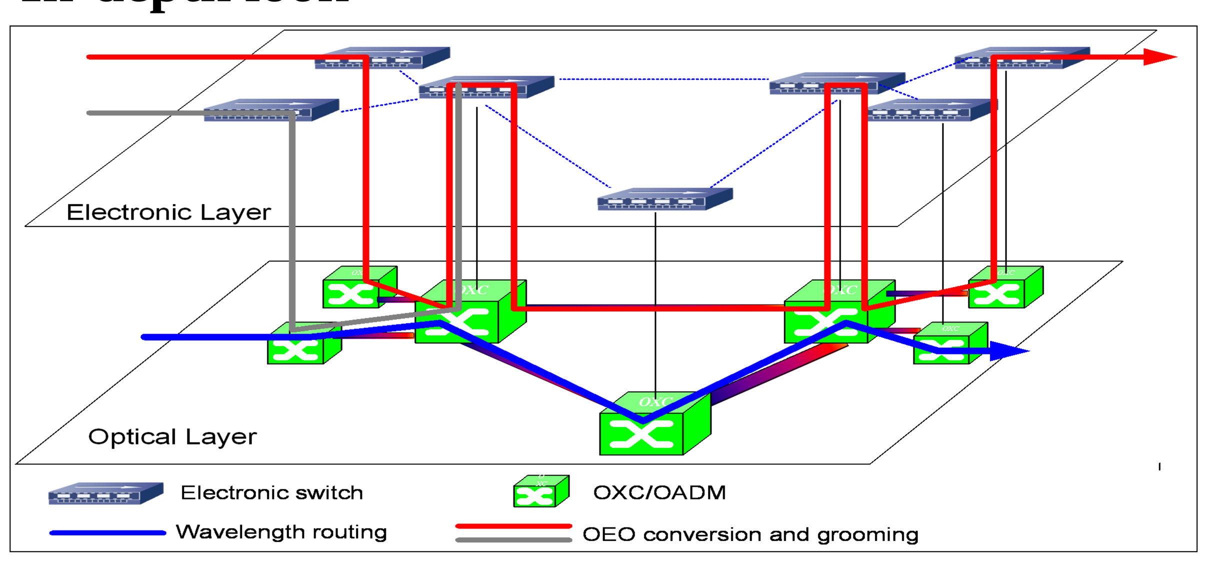
- GMPLS extends MPLS concept of packet switching to include wavelength switching.
- IP/MPLS routers interconnected by Optical Cross Connects (OXC) and fiber links. Incoming traffic groomed at core nodes and transmitted all optically to destination nodes.
- Traffic engineering manages building of lightpaths while grooming traffic flows to optimize network resource allocation.
- Issues arises in two parts:
  - Wavelength blocking: Two wavelengths sharing the same fiber link cannot be assigned the same wavelength.
  - No way to offer differentiated Quality of Service (QoS) since all traffic is routed all optically.

Proposed GMPLS network



- Optical-Electric switching layer added to core nodes. Three types of QoS provided, all-optical (OOO), layer-2 switching and layer-3 store and forward (OEO).
- Network model provides features to do traffic grooming and wavelength conversion via electronic switches at core nodes to avoid wavelength blocking.

In-depth look



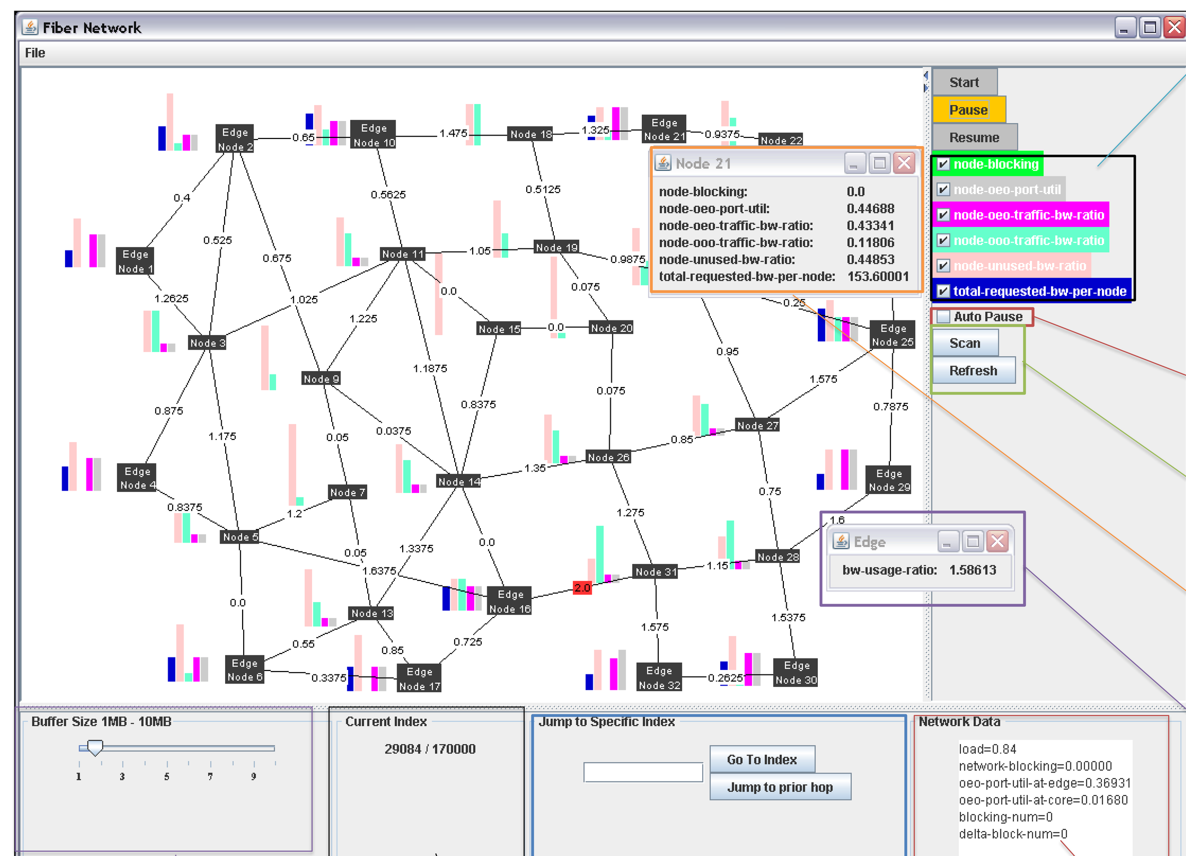
- Incoming optical signal either goes to OXC for all optical bypass (OOO) or to the electronic switch.
- At the electronic switch, signal is either groomed and wavelength converted to a new lightpath or stored in buffer and forwarded to a new lightpath when there are available bandwidth.

Conclusion

The network simulation was very successful in providing a detailed look at how traffic is distributed and travelling through the network. We were able to identify several key hotspots in the network model that required improvements:

1. Core nodes 8 & 12 were not being utilized for traffic routing at all, they were removed from topology in subsequent datasets.
2. The connection from edge node 5 to 16 to 31 was like a information super highway, resulted in under utilization of nearby nodes.
3. Identified key blocking hotspot early on in simulation around nodes 32 & 30. The main cause was because both nodes were isolated from rest of network and could only communicate through one fiber link to rest of network. Solution was to add an additional fiber link from node 16 to 32 to better distribution of packets.
4. Identified Edge Node 16 as a node of high traffic usage, potential for placement of 100 gigabit fiber channel.

Network Simulation Application



- Each checkbox corresponds to the display of the animated graphs next to each node.
- **node-blocking**: the blocking ratio of each node.
- **node-oeo-port-util**: OEO conversion
- **node-oeo-traffic-bw-ratio**: amount of wavelength conversion and traffic grooming traffic
- **node-ooo-traffic-bw-ratio**: amount of all optical bypass traffic
- **node-unused-bw-ratio**: how much bandwidth is unused
- **total-requested-bw-per-node**: indicates amount of traffic that is being generated at each edge node

Auto Pause: pauses simulation when blocking event occurs.

Scan: scans backwards in simulation to display specific blocking events in popup box.
Refresh: manual update for displaying events.

Window that displays detailed statistical data for corresponding node.

Each link has a corresponding wavelength usage ratio (Max: 2.0) , which brings up a edge window displaying the current bandwidth usage ratio of the link.

- **load**: ratio to indicate current load of network
- **network-blocking**: ratio of blocked traffic over the bandwidth requirement of all traffic requests during the simulation.
- **oeo-port-util-at-edge**: OEO conversion at edge nodes
- **oeo-port-util-at-core**: OEO conversion at core nodes
- **blocking-num**: keep tracks of specific source, destination node blocking events
- **delta-block-num**: difference between current and prior blocking-num

Manages read rate of datasets in simulation. Increasing buffer size corresponds to reading and visualizing a larger dataset.

Displays current index in simulation.

Provides functionalities to visualize a specific index in simulation.

About

-The simulation application is written in Java and utilizes the Prefuse and Profusians graphical packages.
- The application implements Object Oriented Programming skills, multi threading technology and some optimization techniques.
- The network topology is based off the 32-node National Science Foundation Network (NSFNET). Each fiber link in the topology consists of 32 wavelength channels operating at 10 gigabits per channel.
- Initial topology consists of 15 edge nodes and 16 core nodes. An edge node mainly forwards packets within and across networks. A core node routes traffic within its network.

Utilization

- The network simulation dataset is generated with variables that are randomized; such as amount of requested traffic at edge nodes, packet source and destination addresses, size of packets etc. The core nodes route traffic according to a set of traffic engineering rules that seeks to find the optimal path to their destinations.

-When load on network gets too heavy, blocking events appear when a path to a destination node cannot be formed and results in the packet being dropped.

- Our main goal through utilizing the simulation application is to identify hot spots in the network architecture where inefficiencies in the topology, hardware and traffic engineering schemes that result in blocking events. By identifying these events, we are able to arrive at solutions that will further improve the overall performance of the fiber network.