

Control of Nonlinear Routing Algorithms in Optical Networks

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Abstract:

In elastic optical networks, digital coherent transceivers modify their symbol rate, modulation format, and forward error correction to best serve the network demands. In a nonlinear elastic optical network, these parameters are inherently coupled with the routing algorithm. We propose to use congestion aware routing in a nonlinear elastic optical network and demonstrate its efficacy for the NSFNET reference network (14 nodes, 22 links). The network is sequentially loaded with 100 GbE demands until a demand becomes blocked, this procedure being repeated 10 000 times to estimate the network blocking probability (NBP). Three routing algorithms are considered: 1) shortest path routing; 2) simple congestion aware algorithm; and 3) weighted congestion aware routing algorithm with 50, 25, 12.5, and 6.25 GHz resolution flex grids. For NBP = 1% using a 50 GHz grid, congestion aware routing doubles the network capacity compared with the shortest path routing.

Key words: Routing Aware; Congestion Control; Shortest Path; Fiber Networks; and Optical Networks

I. INTRODUCTION

Optical networks move towards being able to cope with elastic demands the traditional challenge of routing and wavelength assignment becomes replaced by that of routing, modulation and spectrum allocation.

A. Existing System

The Problem of Existing Solutions in these scenario nodes in the network sends all high priority data to a single sink, tree-based routing is the most appropriate. In this routing scheme, a spanning tree is built with the high priority sink as its root. The setup of such a tree uses controlled flooding from the sink to all nodes in the network. Low priority data, on the other hand, do not need to follow the same routing scheme. This is true because there may be multiple low priority sinks and a node might send data to any of them. For example, temperature readings might be

forwarded to one sink while the motion detection measurements go to another sink, and tree based routing schemes suffer from congestion, especially if the number of messages generated in the leaves is high. This problem becomes worse when we have a mixture of high priority and low priority traffic travelling through the network. This is because low priority messages will cross the tree that is formed to route high priority data in order to reach their destinations. Therefore even when the rate of high priority data is relatively low, the background noise created by low priority traffic will create a congestion zone that spans the deployment from the critical area to the high priority sink. Nodes in this zone become overwhelmed and indiscriminately drop high and low priority messages. These nodes also consume more energy compared to other nodes in the network and hence die sooner. This will lead to only sub-optimal paths being available to route high priority data, or a total loss of connectivity from critical area to the sink even though other nodes outside a single routing scheme is used to route both types of traffic. In such a scenario, routing dynamics can lead to congestion on specific paths. Since congestion is a self-compounding problem, these paths are usually close to each other which lead to an entire zone in the network facing congestion. Congestion can adversely affect the network in two ways. First, it can lead to indiscriminate dropping of data, i.e. some packets of high priority might be dropped while others of less priority are delivered. This happens because sensor nodes are very simple devices and do not have the capability to differentiate packets (i.e. they do not have multiple queues for different priority levels). Second, congestion can cause an increase in energy consumption as links become saturated. This can lead to depletion of the limited energy available in the sensor nodes in the congested area.

B. Proposed System

This paper proposed Congestion Aware Routing (CAR) which is a simple routing protocol that uses

data prioritization and treats packets according to their priorities. We defined a conzone as the set of sensors that will be required to route high priority packets from the data sources to the sink. This paper presented algorithms to build a high priority routing mesh, dynamically discover and configure conzones, and perform differentiated routing. Our solutions do not require active queue management, maintenance of multiple queues or scheduling algorithms, or the use of specialized MAC protocols. The proposed algorithm for RMSA in a nonlinear elastic network utilizing Nyquist pulse shaping is as follows:

- Determine the optimum signal power spectral density given the fiber and amplifier parameters.
 - for a pair of nodes, select the shortest path that avoids the link with the highest spectral usage (determined by measuring the total optical power which is proportional to spectral usage).
 - for this path determine the total number of amplifier spans (100 km herein) in order to determine the received signal to noise ratio (SNR).
 - for this SNR, determine the maximum net spectral efficiency (NSE) based on known relationship between SNR and NSE for a range of polarization division multiplexed formats with Nyquist spectra where variable rate FEC is also included.
 - finally determine the gross symbol rate and assign spectrum to serve the demand between the two nodes.
- We showed that with the inclusion of small play out buffers at the sink, the CAR based routing is suitable for delivering real-time traffic, such as video, over a wide range of conditions.

II. UNDERLYING ASSUMPTIONS IN THE PROPOSED MODEL

In order to facilitate an investigation of congestion aware routing we make the following assumptions in our analysis:

1. The client side data rate is fixed (herein we restrict our Consideration to 100 GbE assumed to be 104 Gbit/s including framing plus an overhead for FEC).
2. Transceivers can vary modulation format and FEC.
3. Channels are Nyquist shaped, having a rectangular spectrum of width equal to the symbol rate.
4. There are negligible guard bands between channels.
5. The network employs single mode fiber and is periodically amplified by a lumped erbium doped fiber amplifier (EDFA) with a bandwidth of 5 THz.

6. The spacing between amplifiers is fixed throughout the network (herein we consider 100 km span length).
7. No optical dispersion compensation is employed and the fiber plant is the same over the entire network.
8. The Gaussian noise model is valid and the nonlinear interference (NLI) adds incoherently such that the total NLI is proportional to the path length.
9. Primary source of noise is from the EDFA within the links and that losses at the nodes may be neglected.
10. In the link where blocking occurs the spectral utilization is sufficiently high that the nonlinear impairments correspond to 100% spectral utilization.
11. We consider the network to become blocking at the point when the first blocked demand occurs.

III. PROPOSED ALGORITHM FOR NONLINEAR RMSA

The proposed algorithm for RMSA in a nonlinear elastic network utilizing Nyquist pulse shaping is as follows:

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4. For this SNR, determine the maximum net spectral efficiency (NSE) based on known relationship between SNR and NSE for a range of polarization division multiplexed formats with Nyquist spectra where variable rate FEC is also included.
5. Finally determine the gross symbol rate and assign spectrum to serve the demand between the two nodes.

IV. MODELING OF NONLINEARITIES

While numerous models exist for fiber nonlinearities, we seek a model that captures the salient features of the nonlinear impairments, but is simple enough to permit complex network studies. Using the Gaussian noise model that if the total available spectrum B is modulated over a single span having an attenuation

coefficient of α and effective length $1/\alpha$, the optimum power spectral density.

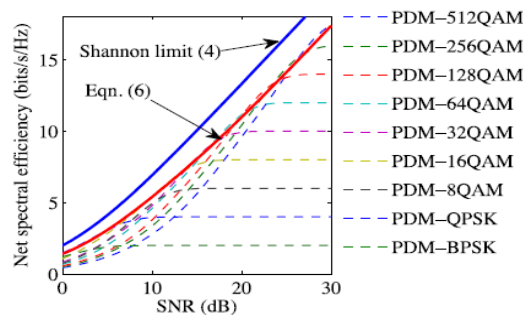


Fig.1. Net spectral efficiency (NSE) versus SNR for various PDM_QAM formats.

V. OPTICAL MODULATION FORMAT

Since the Shannon limit does not indicate the modulation format or the FEC coding overhead that should be employed, we seek an alternative approximate bound as to what might be realizable in practice. In order to consider this for polarization division multiplexed quadrature amplitude modulation (PDM-QAM) constellations we determine using analytical expressions combined with direct simulation of the performance in the presence of additive white Gaussian noise the bit error rate (BER) as a function of SNR. Rather than assume soft decoding we conservatively use the hard decision decoding bound for the binary symmetric channel. From this the NSE as a function of SNR can be obtained for a given cardinality of QAM to give Fig. 1. We note that for a terrestrial core optical transmission network the SNR will typically be in the region of 5 to 25 dB for the fiber and amplifier parameters previously discussed corresponding distances ranging from approximately 100 to 10000 km. Over the region of interest shown in Fig. 2 the NSE that can be realized with PDM-QAM and optimal hard FEC can be approximately bounded. If the optimum launch power spectral density is used then the SNR is uniquely defined by the route through the network. Hence knowing the SNR then using the approximate realizable bound this then defines the appropriate amount of spectrum that should be assigned in an elastic network.

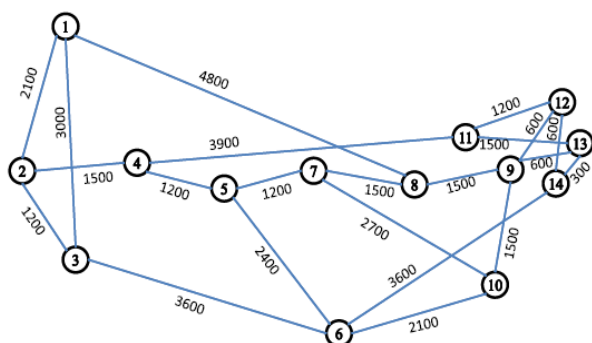


Fig.2. NSFNET topology with the lengths in km marked on links.

VI. ROUTING ALGORITHMS

We consider our benchmark as shortest path (SP) routing with first fit allocation of the optical spectrum, and two congestion aware (CA) variants of shortest path routing that are: **CA1**: Selects the shortest path that avoids the fiber link that is most congested, implemented with Dijkstra's algorithm on the graph where the edge weight for the most congested path has been replaced by infinity. **CA2**: The shortest path through a weighted network, where the weight of an edge joining nodes i and j is given by $W_{ij} = L_{ij} / \eta_{ij}$ where L_{ij} is the physical length and η_{ij} is the proportion of the total spectrum which is still available on that edge. Since the system operates with a constant power spectral density the spectral usage is proportional to the total optical power in any link making congestion a parameter that is straightforward to measure for an installed network.

VII. CONCLUSION

Congestion aware routing has been investigated in nonlinear elastic optical networks and shown to be effective for the reference NSFNET topology. We observe that the network blocking probability (NBP) follows a generalized extreme value distribution, allowing robust estimates of the load for a given NBP to be obtained. When NSFNET is sequentially loaded with 100 GbE demands the proposed algorithm with a 6.25 GHz flex grid, allows the network to support 1744 demands compared to 328 demands using a fixed 50 GHz grid with shortest path routing for NBP = 1%.

VIII. REFERENCES

- [1] O. Gerstel, M. Jinno, A. Lord, and S. J. B. Yoo, "Elastic optical networking: A new dawn for the optical layer?" IEEE Commun. Mag., vol. 50, no. 2, pp. s12-s20, Feb. 2012.
- [2] L. Velasco, M. Klinkowski, M. Ruiz, and J. Comellas, "Modeling the routing and spectrum allocation problem for flexgrid optical networks," Photon. Netw. Commun., vol. 24, no. 3, pp. 177-186, 2012.
- [3] M. Jinno et al., "Distance-adaptive spectrum resource allocation in spectrum-sliced elastic optical path network," IEEE Commun. Mag., vol. 48, no. 8, pp. 138-145, Aug. 2010.
- [4] M. Angelou, P. N. Ji, I. Tomkos, and T. Wang, "QoT prediction for core networks with uncompensated coherent transmission," in Proc. OECC/PS Jul. 2013, pp. 1-2, paper TuQ3-4.

- [5] A. Splett, C. Kurtzke, and K. Petermann, "Ultimate transmission capacity of amplified optical fiber communication systems taking into account fiber nonlinearities," in Proc. ECOC, 1993, pp. 41–44.
- [6] P. Poggiolini, A. Carena, V. Curri, G. Bosco, and F. Forghieri, "Analytical modeling of nonlinear propagation in uncompensated optical transmission links," IEEE Photon. Technol. Lett., vol. 23, no. 11, pp. 742–744, Jun. 1, 2011.
- [7] P. Poggiolini, "The GN model of non-linear propagation in uncompensated coherent optical systems," J. Lightw. Technol., vol. 30, no. 24, pp. 3857–3879, Dec. 15, 2012.
- [8] P. Poggiolini et al., "The LOGON strategy for low-complexity control plane implementation in new-generation flexible networks," in Proc. OFC, Mar. 2013, pp. 1–3, paper OW1H.3.
- [9] S. J. Savory, "Approximations for the nonlinear self-channel interference of channels with rectangular spectra," IEEE Photon. Technol. Lett., vol. 25, no. 10, pp. 961–964, May 15, 2013.
- [10] C.E. Shannon, "A mathematical theory of communication," Bell Syst. Tech. J., vol. 27, no. 3, pp. 379–423, 1948.