ISSN (Online): 1694-0814
www.IJCSI.org

Optical Networks for Cost Monitoring and Reduction

R. Buvanesvari[1], V. Amala Saint Thomas[2], M. Rajeswari[3] and A. Rajaram Kumar[4]

[1,2,3,4] Dept of CSE, Pondicherry University, Perunthalaivar Kamarajar Institute of Engineering and Technology (PKIET) Karaikal, Puducherry, India.

Abstract

This paper focuses on cost reduction and monitoring in optical networks. Optical mesh networks are cost savings with switching systems that are interconnected by point-to-point networks. Transponders play a major role in it. All-optical packet switching has been intensively investigated in recent years as an alternative to static, cross connect based networks. Several switch architectures have been proposed, all of them using buffers made of fiber delay lines. We consider the problem of minimizing the congestion in wireless optical (FSO) backbone networks by placing controllable relay nodes. We propose algorithms for placement of relays in the network under node interface constraints. Further reduction in cost is done by the conversion of optical to electrical at the intermediate nodes. Optical transport networks offer a new level of flexibility in the optical layer allowing various services and thereby improving the efficiency, performance and robustness. An optical path with a transparent feature allows the transmission of signals that are optical and also independent of data rate and modulation format. Client layer protocol provides transparency for the transport layer in optical networks. Thus there is a significant challenge in terms of function, flexibility and monitoring cost.

Keywords: *WRON, Fiber Delay Times, CLR, Demux, traffic profile.*

1. Introduction

Optical networks has a significant feature which was identified as a feasible network for next generation network environment due to potential environments due to its potential advantages to meet rising demands of wide range of communication services. Optical networks have been studied with respect to two perspectives. One is packet switched optical network (PSON) which is efficiently utilizing the network resource similar to packet switched network. And also require optical buffering and synchronization technologies at optical layer in order to overcome output contention blocking of optical packets. Since optical buffer is difficult for actual implementation, PSONs are not feasible. The other is wavelength routed optical network (WRON). This can be implemented with presently available optical devices such as cross–connector and optical filter. WRONs can be operated without optical buffer as a circuit switched network. However, it has a problem of network inefficiency caused by optical constraints and imbalance use of network resources.

Optical network engineers contributed huge endeavors to improve the network efficiency of WRONs. Topology design is used to combine the features of network resources such as optics and electronics. Routing and wavelength assignment is a crucial issue for achieving good performance by improving the utilization of network resources in WRONs. In a wireless backbone network with mobile nodes, the topology of the network needs to be reconfigured as nodes move, to maintain the network performance at a desired level.FSO links offer the flexibility of fast tracking and setup of links. Thus, the topology can be modified quickly to suit the current backbone node locations. Also, in a backbone network designed according to an estimated traffic profile (aggregate traffic); the traffic profile may change over time. Thus, it is necessary to adapt the network topology to achieve the desired performance for the modified traffic profile. This is known as topology control. There has been recent work on topology control in wireless optical networks. The papers address the problem of topology control and routing for a given traffic profile. They consider the problem of changing the topology of the whole network to maximize the throughput or minimize congestion for a given traffic profile. The objective of finding a minimum congestion and minimum physical layer cost network (defined as total BER in the network) is considered. We assume we have no control over the backbone nodes. In such a network, even if the topology design is optimal initially, the performance is expected to degrade over time as nodes move and traffic patterns change. There are transmission range and interface constraints on the backbone nodes. A node can connect only to nodes within its transmission range. The interface constraint is due to the limited number of transmit and receive interfaces the nodes have, which limits the number of links each node can have. Thus, desired links cannot always be established. We propose the use of relays to counter transmission range constraints and propose algorithms to position them in the network to improve the network performance. They are used for forming additional links between backbone nodes. The relays are added such that they form links with backbone nodes without violating the interface constraints. We can change their placement and links to do topology control and improve the network performance. We measure the network performance in terms of the maximum link load (which we call congestion) in the network for the current traffic profile.

2. Optical Technology Networks

The technology is the major obstacle for the optical packet switching (OPS) deployment. Gigabit rates are too high for the slowly improving speed of electronic circuits. Optical technology is thus a promising solution, but still in early phases of development. The key technology issues that have to be addressed include fast optical packet header processing, switching and buffering. The semiconductor optical amplifiers (SOAs) are the key component which determines the cost effectiveness of the OPS as the competing technology to OCS. OPS deployment depends on the switching matrix ability to support the required ns switching times. The criteria for selecting the suitable switching scheme for OPS includes following issues:

1) Switching time - switching time for the OPS should be less than 100ns in order to keep short overhead.
2) Throughput - should be large enough to support core network traffic,
3) Signal degmdarion - includes optical loss and cross-talk. Important for scalability issues in the case where optical regeneration is not applied.

Switching schemes include space switches, broadcast-and-select-switches and wavelength routers. Buffering issues are based on the problem of light trapping. This is achieved by introducing delay in fiber delay lines (FDLs), but the problem arise due to available discrete buffering times and very long fibers needed for longer buffering times (larger memories).

Other solutions between circuit and packet switching, like optical burst switching, evolved as the answer to technology issues. They could be deployed in the next few years, but the OPS remain the long term solution for expected higher traffic volumes and traffic unpredictability.

3. Packet Handling Schemes

There are two different approaches to the OPS network design concerning the employed time frame. The first one called the synchronous scheme assumes that a packet can arrive to the switching fabric only in certain time points. The time scale is divided into time slots. The other one called the asynchronous assumes that a packet can arrive to a switching fabric in any time point. Each scheme implies only the time frame, but not the size of the packet, and thus each can be combined with the fixed-length packets (cells), or variable length packets. However, the majority of proposed OPS networks are based either on the synchronous (slotted) network with cells, or asynchronous network with variable lengths packets.

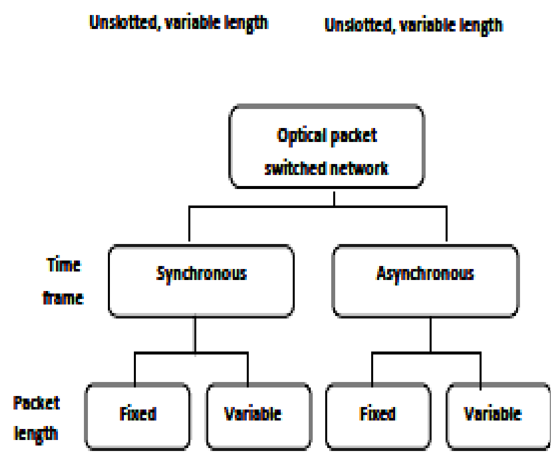


Fig .1 Synchronous and Asynchronous network

The synchronous network approach assumes synchronizer which aligns packets to time slot beginnings. A global synchronization has to be achieved, which represents a problem in large area networks (e.g. Pan- European network). Fixed length packets require fragmentation of large client packets what implies more overhead and makes the node architecture more complex due to reassembly. Bandwidth capacity waste is additionally achieved by transmitting payloads smaller than the header. On the other hand, this approach minimizes blocking and simplifies the FDL based buffers and makes switch matrix reconfiguration. The order of the packet is easy to maintain. This solution is thus more feasible in the middle term perspective. Asynchronous networks with variable packet length don't require fragmentation, nor aligning, but the blocking probability increases. The packet header has to contain the packet length field. The best packet handling scheme is difficult to determine. However, the variable length packets are considered to be a better solution, due to the inherent similarity with the IP packet as the clients for the optical layer.

4. Optical Packet and Optical Packet Processing

Optical packet generally has a payload part containing the client data, and the header. The header and payload are separated (time or wavelength domain), and thus bit rate independent. The header is processed in the electronic domain (due to the immaturity of the optical processing devices), but the payload is transmitted entirely in the optical domain. The header could be transported in a separate channel, but this solution can impose synchronization difficulties between headers and payloads. It depicts a general optical packet format.

Synchronization	Label	Guard Time	Pay load	Guard Time

Fig.2 Packet Format

The following parts of the packet format are common to the majority of propositions:

i) Synchronization - denotes the beginning of the packet. It is essential in asynchronous networks, but also needed in synchronous networks to resynchronize clocks and eliminate time jitter, what is needed to read the label.

ii) Label - contains destination address, length, priority, hop count, etc. The label should provide enough information to route the packet through the network, insure classes of service, and avoid loops. There have been several proposals to label encoding. Sub-carrier Modulation is based on the idea of amplitude modulated sub-carrier on the frequency higher than the payload frequency. The label is modulated into the sub-carrier (e.g. AM), but on the lower bit rate more suitable for electronic processing. The optical carrier is then modulated by the sub-camera. The advantage of this approach is simultaneous transmission of the payload and the label.

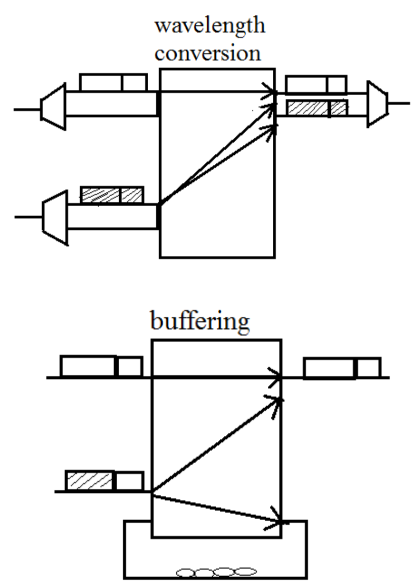
iii) Guard time - time gap that eliminates overlapping of adjacent packets, which could be caused by unequal switching times, or time shifts in header processing (reading writing).

iv) Payload - carries client data. The payload should be transparent to the optical channel speed, as well as to the format of the client data. IP datagram are considered in most cases as the client data, but some other format could be carried by this field as well.

5. Contention Resolution

The efficiency of contention resolution mechanism has a major influence on the network efficiency in terms of packet loss ratio. This problem is solved on the IP layer by using electronic buffers (RAM).This solution is unfeasible in the optical domain, and packer storage is achieved by delaying the signal in FDLs. OPS contention resolution has various solutions , but three can be identified as the basic ones:

1) Improve the capacity sharing by wavelength conversion (WASPNET),
2) Buffering based on FDLs (KEOPS),
3) Deflection routing to avoid or reduce buffering.



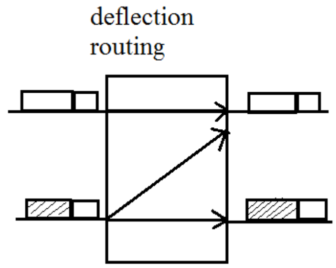


Fig.3 Switch Architecture

Each switch has N inputs and outputs, and comprises 5 parts - the demultiplex sections, cell encoding and the buffer section. The switch could be classified as the output buffered switch with wavelength conversions. The demux section contains N demultiplexers with n exits, assuming that each input carries a WDM signal with n, wavelengths. The cell encoding section contains tunable wavelength converters, which choose the right wavelength according to the free space in buffers as described below. The use of wavelength converters is essential to minimize the number of necessary delay lines. The core part is the $N .n_w, x (B/n_w, +l) N$ unblocking space cross-connect. The number of demultiplexers and wavelengths determine the number of switch inputs, while the buffer capacity determines the number of switch outputs. Each buffer has the same capacity denoted as B, implying that B cells can be stored in the buffer at the same time. A buffer is based on the fiber delay lines. The number of delay lines depends on the number of wavelengths used, and can be expressed as $B/n_w +l$. Delay introduced by the lines varies from 0 (direct connection to the output) to B/n_w T, T being the time slot duration (slotted network assumption). Each delay line carries a multiplexed signal, and is able to store up to n_w cells. It gives the total number of B cells that can be stored. n_w cells can exit the switch using the same exit during each time slot, what corresponds to the number of cells that can enter the switch during one time slot using the same input. There are N buffers, one for each output implying that the number of switch outputs has to be $Nn_w, (B/n_w, +l)$. Number of multiplexers is equal to the number of delay lines (including the zero time connection) or $N (B/n_w, +l)$.

6. Planning Procedure

A channel capacity of 40 Gbps was assumed to reduce the complexity of the analytic algorithm, which depends on the number of used wavelengths. Number of required iterations of algorithm to cover all possible cases is equal to $(l+n)^N$ where n stands for number of used wavelengths and N denotes number of switch inputs. In order to keep the wavelengths low we chose this channel capacity. Number of wavelength used to calculate buffering time and CLR was 4 and 8 per fiber. The planning procedure itself comprises two sets:

1) Worst-case planning, and
2) Planning using the upper CLR constraint.

The term worst-case planning suggests that no considerations about the CLR have been made as network links have been dimensioned just to support the traffic demands. This implies that the number of fibers in each link depends just on the total capacity of demands using the link. The aggregate traffic capacities required on each link has been obtained by routing the traffic demands on the shortest paths. The previous results for the worst-case network modeling can be improved in terms of reducing the demand CLR values under some upper CLR constraint. Figure 4 depicts the steps of the modeling procedure. Previous network dimensioning enters as initial solution to be improved.

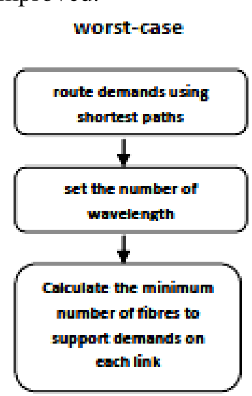


Fig.4 worst-case planning

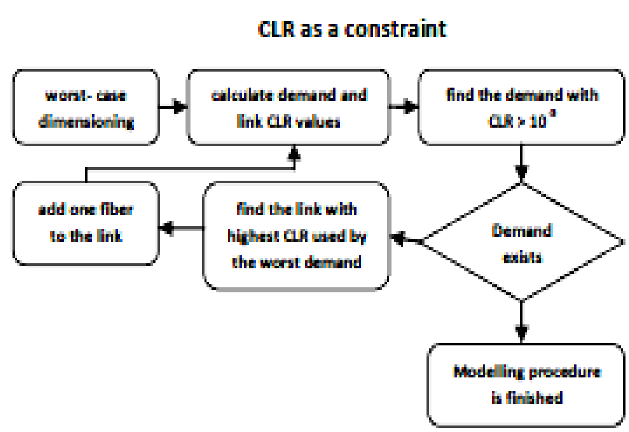


Fig.5 Modeling procedure

7. Traffic Based Greedy Algorithm

Traffic Based Greedy Algorithm (TBGA) assigns profit values to links in the candidate list L based on the traffic profile. Then it sorts L in decreasing order of profit/cost and forms the links in that order. For each link l = {t, h, c} Є L, cost is the number of relays required to form a link (c), and profit represents the total traffic entering the tail node t that is destined for the head node h. The traffic from node t to node h is calculated using flow decomposition for all traffic demands, which gives a set of paths (and corresponding flow values) for each traffic demand. This decomposition is non unique, but any solution gives the correct value of traffic going from node t to node h. Adding a link between the tail and head nodes of the link l is expected to divert a significant part of this traffic through the added link, thus we assign this as the profit. Once the profit values have been calculated, the algorithm is the same as a common greedy heuristic for constrained knapsack problems. TBGA is given in Algorithm (a).

Algorithm (a): *Traffic Based Greedy Algorithm (TBGA)*

Step 1: G'(V, E') = G (V, E)

Step 2: Solve the MCF of Equation on the initial topology G to get a routing f.

Step 3: For each link l = {t, h, c} Є L:

a) Perform flow decomposition to get paths for each profile entry. Let the set of paths for profile entry i be P_i, and let x^p_i denote the demand routed on path p Є P_i.

b) Find the paths (for all profile entries) containing t and h in that order. Denote the set of paths as P^l.

c) Set profit (r_l) of the link as the total traffic flowing through the paths in P^l. Here, $I_{\{E\}}$ is one if event E is true, zero otherwise.

$$r_l = \sum_{i=1}^{M} \sum_{p=1}^{|P_i|} x_i^p \mathcal{I}_{\{p \in P^l\}}$$

Step 4: Sort the candidate list by decreasing r/c ratio

Step 5: Set number of free relays R = K

Step 6: For all links l = {t, h, c} Є L:

- if $R \geq c$, $TI_t > 0$, $RI_h > 0$
  - $E' = E' \bigcup \{t, h\}$
  - $TI_t = TI_t - 1$
  - $RI_h = RI_h - 1$
  - $R = R - c$

Step 7: Output G'

8. Conclusion

The problem of minimizing congestion in a backbone network by using relays has been considered. The relay placement problem is formulated as a constrained knapsack problem, and algorithms are proposed to compute the knapsack item profit values and compute the solution to the knapsack problem. We use the technique of rollout to improve the performance. The simulations show that there is a significant drop in congestion values by placing a small number of relays using our algorithms. The rollout algorithms can be used to obtain good solutions for constrained knapsack problems as well.

References

[1] E. Perkins, Ad Hoc Networking. Addison-Wesley, 2001.

[2] S. Banerjee, and S. Khuller, "A clustering scheme for heirarchical control in multi-hop wireless networks," IEEE INFOCOM, 2001.

[3] K. Xu, X. Hong, and M. Gerla, "An ad hoc network with mobile backbones," IEEE ICC, 2002.

[4] N. A. Riza, "Reconfigurable optical wireless," IEEE LEOS, vol. 1, pp. 70–71, 1999.

[5] T.-H. Ho, S. D. Milner, and C. C. Davis, "Fully optical real-time pointing, acquisition, and tracking system for free space optical link," SPIE, Free-Space Laser Communication Technologies XVII, G. Stephen Mecherle, Ed., vol. 5712, pp. 81–92, 2005.

[6] A. Kashyap, S. Khuller, and M. Shayman, "Topology control and routing over wireless optical backbone networks," Conference on Information Sciences and Systems, 2004.

[7] A. Kashyap, M. Kalantari, K. Lee, and M. Shayman, "Rollout algorithms for topology control and routing of

unsplittable flows in wireless optical backbone networks," Conference on Information Sciences and Systems, 2005.

[8] M. Kalantari, A. Kashyap, K. Lee, and M. Shayman, "Network topology control and routing under interface constraints by link evaluation," Conference on Information Sciences and Systems, 2005.

[9] J. Zhuang, M. J. Casey, S. D. Milner, S. A. Gabriel, and G. Baecher, "Multi-objective optimization techniques in topology control of free space optical networks," IEEE MILCOM, 2004.

[10] A. Desai and S. Milner, "Autonomous reconfiguration in free-space optical sensor networks," IEEE JSAC Optical Communications and Networking Series, vol. 23, no. 8, pp. 1556–1563, 2005.

[11] T. Yamada and S. Kataoka, "Heuristic and exact algorithms for the disjunctively constrained knapsack problem," Information Processing Society of Japan Journal, vol. 43, no. 9, pp. 2864–2870, 2002.

[12] D. P. Bertsekas, Dynamic Programming and Optimal Control. Athena Scientific, 2000, vol. 1.

[13] M. Garey and D. Johnson, Computers and Intractability: A Guide to the theory of NP-Completeness. Freeman and Company, 1979.

[14] T. H. Cormen, C. E. Leiserson, R. L. Rivest, and C. Stein, Introduction to Algorithms, 2^{nd}, The MIT Press, 2001.

[15] R. K. Ahuja, T. L. Magnanti, and J. B. Orlin, Network Flows: Theory, Algorithms, and Application. Prentice-Hall, 1993.

About the Author(s)

R.Buvanesvari received the B.Tech Degree in Information and Technology from Pondicherry University, Puducherry, India, in 2004 and the M.E Degree in Computer Science and Engineering from Annamalai University, Chidambaram, Tamilnadu, India in 2006.Currently, she is working as an Assistant Professor with the school of Computer Science and Engineering at Perunthalaivar Kamarajar Institute of Engineering and Technology (PKIET), Government of Puducherry, Pondicherry University. Her research interests are in the areas of Optical Networks, Network security and Analysis of Routing Algorithms. She has been awarded several awards and merits certificate for her teaching and she is the author of a text book on E-Commerce. She is a life member of ISTE.