Research on Multicast Traffic Grooming Algorithm under the Constraint of Sparse Light Splitter Configuration

Li Du\textsuperscript{a}\textsuperscript{*}, Bing Zhang\textsuperscript{a}, Yang Jiao\textsuperscript{a}

\textsuperscript{a}College of Information Science & Engineering, Northeastern University, Shenyang, 110819, China

Abstract

The problem of multicast traffic grooming under the sparse light splitter configuration is investigated. A comprehensive multicast traffic grooming algorithm (CMGA) is proposed. It uses a new auxiliary grooming graph, and saves the rare resources of the network through setting the suitable values for sides. It can reduce business blocking probability by comprehensively using the strategy of single-hop, multi-hop and building light tree based on the new auxiliary grooming graph. The simulation results show that CMGA performs better at using limited network resources with the MHG algorithm in kinds of traffic load, optical wavelength number, and multicast business proportion.

© 2011 Published by Elsevier Ltd. Selection and/or peer-review under responsibility of Harbin University of Science and Technology. Open access under CC BY-NC-ND license.

Keywords: multicast; traffic grooming; auxiliary grooming graph; business blocking probability; constraint of sparse light splitter configuration

1. Introduction

In the optical network of WDM, compared with the bandwidth of a wavelength unit, bandwidth granularities in most of various traffic requests are smaller. If every traffic request is assigned to a single wavelength channel, network resources will be wasted inevitably and largely, and the lack of bandwidth resources will be caused as a result of the number limitation of wavelength in optical fiber or other reasons. So, it is impossible and unreasonable to request a special connection for every traffic request\cite{1}. The technology of traffic grooming can integrate many traffic requests with small bandwidth granularity to an optical channel with a high volume in order to transmit and raise the utilization ratio of network

\textsuperscript{*} Li Du. Tel.: +8613840434540

\textit{E-mail address: duli@ise.neu.edu.cn}
resources [2]. With the development of network technology and the variation of user requirement, multicast traffic is increasingly popular because the bandwidth of most multicast traffic is far smaller than the bandwidth of a wavelength unit [3]. As a result, the researches on this multicast traffic have a very great significance.

The previous traffic grooming algorithms [4-6] are mostly aimed at saving wavelength resources, without consideration of various restrictions in actual networks [7]. Considering the high cost and energy loss, light splitter shouldn’t be configured in the whole network, so a multicast traffic grooming algorithm under the constraint of sparse light splitter configuration is brought up in this paper and proved a better performance through simulation.

2. Method of constructing the auxiliary grooming graph

In order to reflect the condition of usage of network resources and find appropriate grooming route rapidly, a new auxiliary grooming graph [8] is raised in the algorithm of this paper. The constructing steps as follows:

[Step1] Construct $W$ wavelength plane. Divide every node into some input terminal and output terminal in every wavelength plane. Physical MI node has only one input terminal and output terminal. The number of input terminal and output terminal of physical MC node depends on the degree of this node (the number of near nodes linked on the physical topology).

[Step2] Connect input terminals and output terminals inside every node with light splitting side.

[Step3] According to the structure of network physical topology, connect output terminals in the identical wavelength and input terminals near these output terminals with wavelength side.

[Step4] With regard to the nodes having the ability of wavelength conversion, connect output terminals on every wavelength plane with wavelength conversion side.

[Step5] Assure the cost of every side of auxiliary grooming graph.

The physical topology of Fig.1 shows the structure of the new auxiliary grooming graph. Fig.1 is a network having 4 nodes. Node 2 is physical node, and Node 1 and Node 3 and Node 4 are all physical MI nodes. The link in this network is composed of a pair of unidirectional optical fiber with contrary direction. Every optical fiber supports 2 wavelengths. Thus, auxiliary grooming graph has 2 wavelength planes. The auxiliary grooming graph is constructed as Fig.2.

Fig. 1. Physical topology                                                                                          Fig. 2. Auxiliary grooming graphs
Generally, a multicast traffic request in network can implement grooming through different routing methods. In order to choose a route that can save sparse current network resources better than any others and decrease traffic congestion ratio, the cost value should be configured for every side in auxiliary grooming graph according to network resources configuration and current using condition. Side cost value \( \text{cost} \) is defined as Formula (1),

\[
\text{cost} = \begin{cases} 
C_e, & e \in E_w \\
C_{ wc}, & e \in E_{ wc} \\
\sum_{e \in E_{tw}} C_e, & e \in E_i \\
C_s, & e \in E_s
\end{cases}
\]  

(1)

In Formula (1), \( C_e \) represents the cost value of wavelength side \( E_w \). \( C_{ wc} \) represents the cost value of wavelength conversion side \( E_{ wc} \). \( C_s \) represents the cost value of light splitting side \( E_s \). \( E_i \) represents optical route side. \( E_{tw} \) represents the set of wavelength side that multicast light-tree goes through. \( C_{ ei} \) represents the cost value of these wavelength side.

3. Description of CMGA algorithm and analyzing of simulation

The choice of traffic grooming strategy decides grooming path of multicast traffic request, and different multicast traffic grooming effect will be caused because of different combination of strategies. CMGA algorithm uses the combination of three strategies. It implements grooming single-hop grooming strategy using built light-tree surplus bandwidth which is identical with newcome multicast traffic source nodes and destination nodes. It also implements grooming multi-hop grooming strategy using built light-tree which is identical with newcome multicast traffic destination node and different with source node, and through connection of optical paths of two light-tree source nodes. The two strategies can both utilize surplus bandwidth of built light-tree efficiently, but they are hard to implement because of many restrictions. In order to compensate their deficiency, the third strategy is used. It is a newly-built light-tree grooming strategy, using available wavelengths in new auxiliary grooming graph, to build a light-tree from source node to all destination nodes.

We can set \( R(s, D, b) \) as multicast traffic request, \( s \) as source node, \( D \) as the set of destination nodes, \( b \) as bandwidth needed by traffic. In CMGA algorithm, try to dredge using single-hop grooming and multi-hop grooming strategy firstly. Assign resource if succeed. Construct auxiliary grooming graph if fail, and dredge using newly-built light-tree strategy in the figure. CMGA algorithm is described as follows:

[Step1] Wait for multicast traffic request \( R(s, D, b) \). Jump to Step2 if the request is connection building request. If the request is connection releasing request, the algorithm releases resources occupied by multicast traffic and go on waiting.

[Step2] In physical topology, compute grooming route for newcome multicast traffic request \( R(s, D, b) \):

a. Search for built light-tree that includes all destination nodes of newcome multicast traffic request. Jump to b if succeed. Else, jump to Step3.

b. Check whether source node of found light-tree is identical with source node of newcome multicast traffic request. If identical, jump to Step5. Else, build a new optical path using the shortest path algorithm to connect source node of newcome multicast traffic request and source node of built light-tree. Then, jump to Step5. If new optical path fails to be built, jump to Step3.

[Step3] Construct auxiliary figure according to current network using condition and bandwidth needed by newcome multicast traffic request. In the figure, optical path side of surplus bandwidth greater
than b, unoccupied wavelength side, available light splitting side and available wavelength conversion side are included, and configure cost of every side according to Formula (1).

[Step4] Search route for newcome multicast traffic request R(s, D, b) adopting MPH algorithm in the auxiliary grooming graph. If succeed, jump to step5. Else, jump to Step1.

[Step5] Assign resources for multicast traffic request R(s, D, b), then jump to Step1.

CMGA algorithm is simulated in this paper in order to analyze its performance. The requirement in this simulation as follows:

Fig. 3. NSFNet topology

(1) The simulation network is designed as Fig.3, NSFNet, including 14 nodes and 21 links. The connection between two nodes is bidirectional link. There is an optical fiber on every direction. The wavelength number in every optical fiber is the same, and the volume of every wavelength is OC-192. The nodes in network are physical MC nodes and physical MI nodes. All physical MC nodes have the ability of wavelength conversion. Node 1, 3, 5, 8, 9, 12 are physical MC nodes. Others are physical MI nodes.

(2) The traffic requests arrive and leave dynamically. The number of traffic request per unit obeys Poisson distribution (the parameter is $\beta$), and the traffic duration obeys negative exponent distribution (the mean value is $1/\mu$). The network load can be represented as $\beta/\mu$ and the unit is Erlang (the value of $\mu$ is set to 1 in this simulation).

(3) Multicast traffic or unicast traffic is generated at random. The ratio that multicast traffic is contained in all traffics is represented as $R_m$, and the ratio that unicast traffic is contained in all traffics is represented as $R_u$.

(4) The source nodes and the destination nodes of all connection request R(s, D, b) are selected at random in all nodes. The bandwidth needed by every traffic request is b, and $b \in (OC-3, OC-12, OC-48, OC-192)$, and $OC-3: OC-12: OC-48: OC-192=3:3:3:1$.

The outcome of the simulation indicates that in the network the traffic congestion ratio is obviously affected by the number of MC nodes, network load, the number of optical fiber wavelength, and the ratio that multicast traffic is contained. The more is the number of MC nodes in network; the lower is the traffic congestion ratio, and when the number of MC nodes exceeds half of all nodes, the effect to traffic congestion ratio caused by the increasing number of MC nodes will be much lower.

What is shown in Fig.4 is that:

a. Following the increasing ratio of multicast traffic contained in all traffic, the traffic congestion ratio of MHG algorithm and CMGA algorithm is increasing. This is because bandwidth resource needed by unicast traffic is less than multicast traffic, and is immune to physical MC node sparse configuration.
b. The traffic congestion ratio of MHG algorithm is always higher than that of CMGA algorithm, and the difference value of them increases as the ratio of multicast traffic increases. That is to say, the larger is the ratio of multicast traffic, the more evident is the advantage of CMGA algorithm.

What is shown in Fig.5 is that:

a. Traffic congestion ratio increases following the increasing network load.

b. When network load is constant, traffic congestion ratio of CMGA algorithm is lower than that of MHG algorithm. This is because most of traffic requests in network need little bandwidth, and will not occupy the whole bandwidth of a wavelength unit. When using CMGA algorithm, surplus bandwidth of existing traffic is better made use of, so traffic congestion ratio decreases.

c. When network load is increasing, the increasing tendency of traffic congestion ratio of MHG algorithm is becoming fiercer, whereas the tendency of traffic congestion ratio of CMGA algorithm is more gently. So we can say that CMGA algorithm is more immune to the change of network load, and has more advantages especially when network load is large.

What is shown in Fig.6 is that:

a. When the number of optical fibre wavelength increase, traffic congestion ratio of the two algorithms both decrease evidently. This is because available resources become more when the number of optical fibre wavelength increases. When network load is constant, the number of services which fail to build connection will decrease, so traffic congestion ratio decreases.

b. Traffic congestion ratio of CMGA algorithm is always lower than that of MHG algorithm, even though the number of optical fibre wavelength is changing.
Constrained in the condition of light splitter sparse configuration, this paper raises an integrated multicast traffic grooming method based on auxiliary grooming graph, CMGA algorithm. It uses new auxiliary grooming graph and syncretizes three grooming strategies, single-hop grooming, multi-hop grooming and newly-built light-tree, which can make use of limited network resources sufficiently and decrease traffic congestion ratio effectively, no matter in kinds of network load, or in kinds of optical fiber wavelength numbers, or in kinds of multicast business proportion.

References

[1] KHALIL A, ASSI C, HADJIANTONIS A, et al. On multicast traffic grooming in WDM networks, IEEE Symposium on Computers and Communications. Alexandria: IEEE Press, 2004.
[2] Huang Shan-guo, Gu Wan-yi, Zhang Yong-jun. IP Data Optical Network and Application, Beijing: People Post and Telecommunications Press, 2008, 76-192.
[3] Wang Xiong, Wang Cheng. Dynamic Multicast Traffic Grooming Algorithm in WDM Network, Electronic Science and Technology University Journal. 2007(5).
[4] K.Zhu, H.Zhu, B.Mukherjee. Traffic engineering in multi-granularity heterogeneous optical WDM mesh networks through dynamic traffic grooming, IEEE Network, 2003, 17: 8-15.
[5] G.V.Chowdhary, C.S.R.Murthy. Grooming of multicast sessions in WDM mesh networks, Proceedings of the First International Conference on Broadband Networks (BroadNets'04), 2004.
[6] Cai Lu, Lemin Li. Dynamic Multicast Traffic Grooming for Survivable WDM Mesh Networks, IEEE, 2008.
[7] Yan Feng-ping, Pei Li, Ning Ti-gang. Optical Fiber Communication System, Beijing: Science Press, 2006, 208-224.
[8] Y. Zhou, G.-S. Poo, S. Chen, P. Shum, L. Zhang. Dynamic multicast routing and wavelength assignment using generic graph model for wavelength-division-multiplexing networks. IET Commun, 2008, 2(7): 951-959.
[9] H.Zhu, H.Zang, K.Zhu, B.Mukherjee. A novel generic graph model for traffic grooming in heterogeneous WDM mesh networks, IEEE/ACM Transactions on Networking, 2003, 11: 285-299.
[10] Jianping Wang, Junling Yuan, Xianwei Zhou. A novel multicast routing algorithm in sparse splitting WDM network with power attenuation constraint, Photonic Network Communications, 2009, 19(2): 134-143.