A load balancing multi-path routing scheme based on effective voids for optical burst switching networks

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Abstract  Multi-path routing in the optical burst switching (OBS) networks can reduce the burst loss probability (BLP) by distributing the data burst traffic to multiple paths, compared with single path routing. Unlike the other multi-path routing schemes without considering the carrying capability of the routes, a new multi-path routing scheme based on effective voids (MPEV) is proposed to balance the load of multi-path and reduce the BLP in the paper. MPEV scheme first obtains the information on effective voids of the bottleneck link of multi-path by sending a probe packet periodically. The effective voids can accommodate data bursts and accurately represent the available channel resource that is the main determinant of the BLP for OBS networks without optical random access memory. Then MPEV scheme distributes the burst traffic between an ingress node and an egress node to multiple link-disjoint paths by the ratio of the effective voids. More traffic is distributed to the path that has more effective voids, and vice versa. And the distributed amount is proportional to the effective voids of the bottleneck link. So MPEV scheme can balance the load of multi-path routes and can effectively reduce the BLP by avoiding the high load of a single path. And it is easy to implement and agilely adapt to dynamic network traffic. The performance of MPEV scheme is analyzed by queuing theory and is evaluated by simulation. The numerical results show that the proposed scheme can effectively reduce the BLP and balance the traffic load over multiple paths at the same time.

Keywords  optical burst switching, multi-path routing, effective voids, bottleneck link, balance traffic load


1 Introduction

Wavelength division multiplexing (WDM) can meet the huge bandwidth demands of the next generation Internet. Optical burst switching (OBS) [1], which combines the advantages of optical circuit switching (OCS) and optical packet switching (OPS), is considered as a promising switching technology for IP over WDM. In OBS networks, IP packets with the same egress address (i.e., destination address in OBS networks) are assembled into a data burst (DB) at the ingress nodes (i.e., source nodes in OBS networks), and a corresponding burst header packet (BHP) is created. Information about the DB, e.g., DB length,
offset time, source address and destination address, is contained in the BHP. The BHP is sent before its corresponding DB’s transmission, and the time between the two transmissions is called offset time. After O/E conversion, a BHP is processed in the electronic domain at each core node to reserve data channel resource and configure the switching fabric for the forthcoming DB at the core node. After that, the DB can pass the core node without any O/E/O conversion being performed on it. At the egress node, a BHP is destroyed and a DB is disassembled to many IP packets.

The routing scheme can be used to alleviate the congested link and reduce the burst loss probability (BLP) in the OBS networks without any optical random access memory. A single-path static routing scheme is proposed to minimize the maximum congested link or the maximum end-to-end congested path in [2]. The scheme utilizes an integer linear programming method and its complexity is high. In the routing scheme base on link availability state, the node computes the availability states of each route leading to each specific destination and selects the route which has the minimum byte loss rate [3]. But the link information is frequently broadcast to all other OBS nodes and the cost is high. Compared with the SP routing above, multi-path routing can alleviate the congestion and decrease the BLP by allotting DBs to the multi-path routes.

Currently, many multi-path schemes have been proposed for OBS networks. Equal proportion multi-path routing (EPMR) and Hop Length-based Multi-path Routing (HLMR) distribute DBs to multiple paths by keeping a fixed proportion of total traffic [4]. The two schemes cannot dynamically distribute the traffic by network status information, and may lead to high BLP in dynamic network traffic scenario. In [5,6], a nonlinear optimization method is proposed to obtain the optimal splitting proportion of multi-path routes, and the prior information of the network traffic of all edge nodes is required in this method. So its computational complexity is very high. In the Adaptive Multi-path OBS Routing (AMOR) algorithm [7], the splitting proportion is initially set to a value that is inversely proportional to the hop number, and the proportion will be dynamically adjusted once a path cost is 20% greater or lower than the optimal path cost, which is determined by the link BLP and the number of hops to destination jointly. However, the adjustment granularity of AMOR algorithm is coarse and it cannot adapt to quickly changing network traffic.

In order to make up for the deficiency of the scheme above-mentioned and get a low BLP, a new multi-path routing scheme based on effective voids (MPEV) is proposed in the paper. MPEV scheme sends probe packets periodically in the ingress nodes and gets the effective void information of the bottleneck link of multi-paths, which can precisely stand for the available channel resource of the link. Then the scheme distributes the traffic of a source-destination node pair (SD pair, or an ingress-egress node pair) to link-disjoint multi-path routes according to the distribution ratio that is proportional to the effective voids of the bottleneck link. In the OBS networks without optical random access memory, the BLP of a node is mainly determined by the data available channel resource of output link. So MPEV scheme adopts the distribution based on effective voids can reduce the BLP. The distribution ratio is proportional to the effective voids of the bottleneck link of multi-path routes. This helps to balance the traffic load of multi-path routes and avoid the high load of a single path. Compared with AMOR algorithm, the adjustment granularity of MPEV scheme is fine, and it can agilely adapt to dynamic traffic. Only considering the bottleneck link reduces the implementation complexity of MPEV scheme.

The rest of the paper is organized as follows. In Section 2, effective void and the main idea of MPEV scheme are discussed, and the MPEV scheme is analyzed by queuing theory. The performance of the MPEV scheme is evaluated by the simulations in Section 3. Finally, some conclusions are drawn in Section 4.

2 Load balancing multi-path routing based on effective voids

2.1 Effective void

In OBS networks, offset time is the difference time between sending a BHP and its corresponding DB. The offset time is related to the hop number between the core node and destination egress node. For