Heuristics for providing guaranteed service in DAVID metro network

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Abstract *This paper proposes four heuristic solutions to support two categories of service in the DAVID metro network, namely bandwidth- and delay-guaranteed service and best-effort. Some simulation results assess the merits of each solution.*

Introduction

DAVID (Data And Voice Integration over DWDM) [1] is an IST project funded by the European Commissions. It aims at designing an optical packet-switched (OPS) network by developing networking concepts and technologies for future optical networks. The DAVID network architecture encompasses both metropolitan and geographical scales. This paper focuses on the metro segment of the DAVID project. In particular it deals with the problem of supporting two service categories, namely an on demand bandwidth and delay service to support *High-Priority* traffic (HP) for applications such as Internet telephony, and video-conferences, and the conventional *Best-Effort* service (BE).

DAVID metro network

The DAVID metro network consists of several uni-directional WDM rings interconnected in a star topology by an optical switch called Hub (Fig. 1). *W* wavelengths are available on each ring, plus one devoted to network control channel. All wavelengths are time-slotted. Slots are aligned on all wavelengths of the same ring, so that a multi-slot is available at each node in each time slot. Nodes belonging to the same ring access the same set of WDMA/TDMA shared resources using a MAC protocol. No packet buffering in optical domain is used in the metro network. The Hub behaves like a space switch between rings performing a permutation from input rings to output rings in every time slot to provide optical interconnection among rings. The permutation is known for each time slot in each ring: the Hub labels the multi-slots (using the control slot) to identify the destination ring for the next time they return to the Hub. Ring interconnections (i.e. permutations) are dynamically modified at the Hub following a scheduling algorithm. The aim of the scheduling algorithm is to provide an amount of bandwidth, close to instantaneous requirements, to the node pairs.

Scheduling problem formalisation

The management of BE traffic is a relative easy task as has been studied in [2]. The Hub can schedule the permutations according to both traffic measurements and congestion signals issued by nodes allowing the nodes to decide whether to transmit and/or to receive by checking on the control slot of the multi-slot what has been already transmitted by upstream nodes. To guarantee the HP traffic requirements and not precluding the BE traffic too much, a kind of admission policy has to be applied at the Hub to bound the amount of HP traffic. We adopt a connection-oriented approach where the Hub establishes the connections between the nodes reserving the required resources along the rings. Therefore, the scheduling algorithm performs two tasks: (1) maintaining the virtual, time-slotted connections between the nodes, and (2) fairly sharing the unreserved bandwidth to the BE traffic.

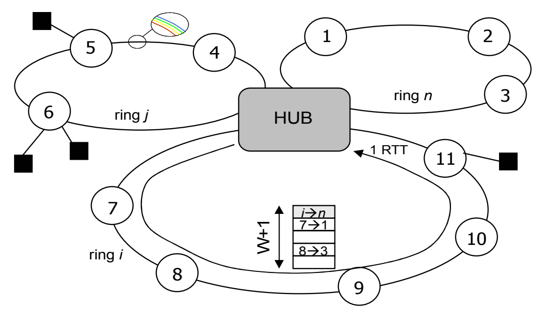

Fig. 1. DAVID metro network

To solve the former task the architecture of the network, which introduces specific problems, must be taken into account, while for the latter the same solution proposed in [2] is adopted.

Firstly, the scheduling has to be subjected to the following constraints:

- Each node can transmit and receive at most a packet in each multi-slot (we refer to this constraint as *transceiver* constraint).
- A request should be accepted only when it can be fully satisfied (*atomicity* constraint).
- An already existing connection cannot be blocked by the allocation of a new connection (*transparent* constraint).
- The permutation is the same for all wavelengths of each ring, i.e. the Hub can perform only ring-to-ring switching (*multi-slot* constraint).

On the other hand, a packet collision may occur between the packets injected in the downstream ring (after having been switched at the Hub) and the slots reserved by the Hub in the upstream ring for the transmission of HP traffic. We refer to this problem as *in-transit* constraint.

The computational complexity of this problem is NP-complete, since it can be reduced to a generalisation of the well-known Knapsack problem [3]. The problem can be solved in polynomial time if we adopt heuristic solutions, which decrease the complexity of the scheduling problem accepting some degree of worse performance.

Heuristic solutions

A. First-fit

The Hub schedules each incoming HP request using a *first-fit* (FF) principle taking into account all the above-described constraints by scanning from the beginning of available resources to the end, until the request is satisfied or the end is reached. In this case, the Hub has to know the position of each node along the rings and has to inform the nodes about the HP reservation of their downstream ring to meet the in-transit constraint between BE and HP packets.

B. Time and frequency decoupling

To simplify the FF algorithm avoiding the in-transit constraint, the transmission and the reception resources can be logically disjointed in the frequency or the time. For the frequency decoupling (FD) (case studied in [4]), the nodes use *W*/2 wavelengths to transmit, and the rest to receive packets. This solution precludes the space reuse since all packets have to be switched at the Hub before being received. In the time decoupling (TD) case, the time is organised in Round-Trip Time (i.e. the time needed by each slot to circulate around a ring, assuming the same value for any ring). Therefore, the nodes can use only one RTT out of two to transmit the packets. In this case, the space reuse is available since the node can receive every time. For both solutions, the Hub can schedule the requests without knowing the node position along rings.

C. Hybrid solution

FD and TD have the drawback that the available bandwidth is halved by the fixed resource partitioning. This problem can be overtaken if the decoupling is applied only to the HP traffic, and not to the BE traffic. In this case, the Hub can schedule the requests without knowing the node position along rings but has only to inform the nodes about the HP reservation of their downstream ring as in the FF case.

Numerical results

The simulated network consists of *N*=40 nodes uniformly distributed among *R*=4 rings, each one with *W*=5 wavelengths (4 for data and 1 for control). The BE traffic of each node is modeled using a self-similar model composed by 16 i.i.d. strictly alternating ON/OFF Pareto sources. The HP traffic is modeled using a two-state Markov chain.

Fig. 2 shows the total (BE+HP) throughput of the four solutions as a function of offered load (with HP = 30% of total load) considering uniform traffic distribution. The Hybrid solution obtains the best performance.

Fig. 3 shows the throughput as a function of the HP relative load percentage assuming 100% total load and unbalanced traffic distribution; 70% of traffic is intra-ring (where the space reuse is possible), the rest is uniformly distributed among the inter-rings. The figure depicts the BE and total (BE+HP) throughputs. The space reuse exploitation makes TD better than FD, while Hybrid still achieves the best results as far as HP traffic requires less than 50% of total resource

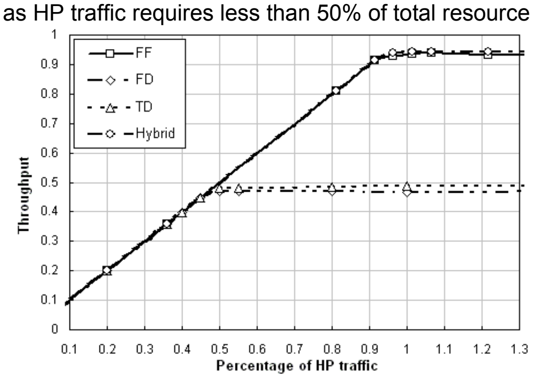

Fig. 2. Throughput vs. offered load (HP load = 30%)

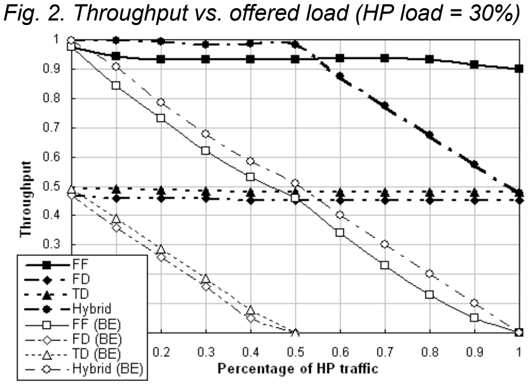

Fig. 3. Throughput vs. HP load percentage (load = 1)

Table 1 compares the complexity of the four solutions showing the average running time to obtain a point of the previous figures.

Table 1. Average running times of four solutions

	FF	FD	TD	Hybrid
Time	2298 s	1354 s	1298 s	1711 s

Conclusions

In this paper we have presented four heuristic methods for providing bandwidth- and delay-guaranteed service and best-effort to the DAVID metro network. The simulation results show that the Hybrid solution is preferable when the HP traffic is less than 50% of total resources. TD and FD solutions can be adopted when the bandwidth on network links is not a bottleneck.

Acknoledgements

This work is partially funded by the EC (IST project DAVID, IST-1999-11742) and by the MCYT (Spanish Ministry of Science and Technology, FEDER-TIC2002-04344-C02-02).

References

1 L. Dittman et al. IEEE JSAC, in press
2 A. Bianco et al. PNC, vol. 5(1), 2003, page 5-22
3 H. Papadimitriou et al. Dover, 1998
4 A. Bianco et al. ONDM 2003, page 623