Nodes' Clustering in WDM Star Networks with Real-Time Traffic

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***Abstract*— This paper proposes a novel scheduling scheme, namely Node Clustering with Prioritized Scheduling (NOC-PS), which is designed to handle real-time traffic in Wavelength Division Multiplexing (WDM) star networks. NOC-PS is based on clustering techniques, while it takes into account the priority information of data packets. The clustering process aims at organizing the network nodes into groups in terms of their packets' requests per channel. Then, NOC-PS rearranges the nodes' service order beginning from the cluster with long-length requests and ending to the cluster with short-length requests. The novelty of NOC-PS is that it applies separate clustering to nodes with high and low priority packets, while it also differentiates their scheduling, since high-priority packets have the privilege of being scheduled prior to low-priority ones. The simulation results indicate that the proposed scheme leads to a significantly higher throughput-delay performance for real-time traffic, without sacrificing the performance of non-real-time traffic.**

***Index Terms*— Clustering, packet priority, real-time traffic, scheduling, WDM star networks.**

I. Introduction

Popular media-access control (MAC) protocols for local area WDM single-hop networks [1] adopt a sequential service order for nodes' requests and, furthermore, they handle nodes' traffic considering that all their packets are of equal priority [2], [3]. However, in recent years, real-time traffic is considered to represent $25-30\%$ of the Internet traffic. In the literature, real-time traffic is treated as high-priority packets, while non-real-time traffic is treated as low-priority packets [4]. Given that real-time traffic, such as audio and video, has stricter time constrains than non-real-time traffic, such as text, e-mail or file transfer, there is a need of MAC protocols which will meet the quality of service (QoS) requirements.

This paper presents a novel pre-transmission coordination scheduling algorithm for optical WDM star networks, namely Node Clustering with Prioritized Scheduling (NOC-PS). The proposed NOC-PS scheme is based on the clustering [5], [6] of the network's nodes, while at same time, it takes into account the priority information of data packets. Its core idea is to handle real-time traffic applying separate clustering to nodes with high and low priority packets. During the clustering process, NOC-PS aims at creating groups of similar nodes in terms of their packets' requests per channel. The goal is to rearrange the service order of the network nodes beginning from the nodes belonging to the cluster with long-length requests and ending to the nodes of cluster with short-length requests. A serious drawback of sequential service order schemes is that they schedule the nodes' traffic without taking into account their specific requests. As a result, nodes with short-length requests (few packets) may transmit prior to those with long-length requests leading to decreased channel utilization because of many unused timeslots. Nodes' rearranging introduced by NOC-PS leads to significantly upgraded network performance due to the decreased unused timeslots. The novelty of NOC-PS is that, apart from prioritizing nodes traffic in terms of the length of their requests, it also provides priority to real-time traffic. In practice, it applies separate clustering on nodes with high and low priority packets, and, then, it differentiates their scheduling, since high-priority packets have the privilege of being scheduled prior to low-priority ones. Overall, NOC-PS schedules traffic according to the following order: high-priority long-length requests, high-priority short-length requests, low-priority long-length requests and, finally, low-priority short-length requests.

Discovering similar nodes requests and rearranging them properly on the basis of their length and their priority information can lead to higher network performance without aggravating the time complexity of the scheduling algorithm. Network nodes' clustering has been previously applied contributing in network's performance upgrading [7], [8] without, however, handling real-time traffic.

The remainder of this paper is organized as follows. Section II provides the network issues and presents related packet scheduling algorithms for WDM star networks, while clustering background is given in Section III. Section IV presents the proposed scheduling algorithm, while Section V discusses the simulation results. Conclusions are given in Section VI.

II. Network Issues

Consider a local area WDM single-hop network with broadcast-and-select architecture, consisting of n nodes, which are connected in a passive star coupler via a two-way optical fiber, and w data channels (wavelengths), where $n \geq w$, which are of the same capacity. According to Table I, $U = \{u_1, \ldots, u_n\}$ denotes the set of network's nodes while $\Lambda = \{\lambda_1, \ldots, \lambda_w\}$ indicates the set of data channels. Even though

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TABLE I

BASIC SYMBOLS' NOTATION

Symbol	Description
n, w	Number of nodes and data channels
$U = \{u_1, \ldots, u_n\}$	Set of network's nodes
$\Lambda = \{\lambda_1, \ldots, \lambda_w\}$	Set of data channels
D	$n \times w$ demand matrix
D_h	$n \times w$ demand matrix of high-priority packets
D_l	$n \times w$ demand matrix of low-priority packets
k	The upper bound of messages' length
t	Schedule's length in timeslots
$L = \{l_1, \ldots, l_t\}$	Set of timeslots
S	$w \times t$ scheduling matrix
Cl	Clustering process
noc	Number of clusters
C_j	Cluster, $j = 1, \ldots, noc$
c_j	Cluster representative
$Means$	$noc \times w$ clusters centroids' demand matrix
$dist$	Nodes distance over wavelengths
J	Criterion function

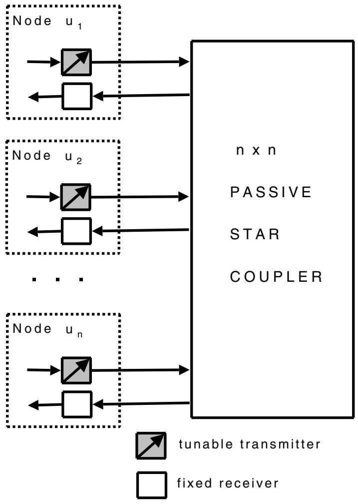


Fig. 1. Network Topology

there is no separate control channel for coordination, the proposed protocol is still pre-transmission coordination-based, since the set of w data channels are used for both control and data packets [9]. Thus, each node may transmit data on different channels using a tunable transmitter (TT), while it receives packets in a dedicated channel, also known as home channel, using a fixed receiver (FR), as depicted in Fig. 1.

In the above TT-FR implementation, transmission is organized into frames, where each frame consists of a reservation (or control) phase and a data phase. During the reservation phase, the n nodes include in their control packets the priority information of their data packets i.e. $p_r = 1$ for high-priority packets and $p_r = 0$ for low-priority packets, while they also send their requests to the common data channels. Nodes' requests are formed as variable-length messages consisting of one or more fixed-length data packets and time is divided into timeslots, where each data packet is transmitted in time equal to a timeslot. Real-time and non-real time requests are recorded in the $n \times w$ D_h and D_l demand matrices respectively, where $d_h(i,j)$ ($d_l(i,j)$) element, $i = 1, \ldots, n$ and $j = 1, \ldots, w$, indicates the number of high-priority (low-priority) data packets at node u_i that are destined for channel λ_j. Based on D_h and D_l, D can be defined as $D_h + D_l$, where $d(i,j)$ element represents the total number of data packets at node u_i that are destined for channel λ_j. The proposed NOC-PS operates in conjunction with a distributed scheduling algorithm and produces the w x t scheduling matrix S, where t denotes the length of the schedule in timeslots. Each $s(i,j)$ element, $i = 1, \ldots, w$ and $j = 1, \ldots, t$, represents the node that transmits on channel λ_i during the timeslot l_j. During the data phase the packets' transmission takes place according to the matrix S which was build during the reservation phase.

A well-known pre-transmission, coordination based scheduling algorithm for optical WDM networks is the Online Interval-based Scheduling (OIS) [2]. OIS incorporates on-line scheduling and has low time complexity $O(nkw^2)$, where k is the upper bound of nodes' requests on each channel. According to OIS each node maintains two lists of time intervals that are available for transmission: one for each channel and one for each node. The algorithm does not assign more than one node at the same time interval on the same channel, in order to keep the schedule collision free. Hence, the transmission is scheduled to the appropriate intervals and the aforementioned lists are properly updated. An extension of OIS, which is based on traffic prediction, is the Predictive Online Scheduling Algorithm (POSA) [3]. POSA has a very effective traffic prediction mechanism aiming at drastically reducing the computation time of the schedule. This mechanism differentiates POSA from OIS, while both of them operates the same scheduling algorithm.

III. CLUSTERING BACKGROUND

A clustering process aims at creating groups of similar items e.g. nodes which exhibit similar traffic patterns. According to Table I, under a particular Cl clustering process noc denotes the number of clusters to be created. The set of nodes that is to be clustered is defined as $U = \{u_1, \ldots, u_n\}$, while $C_1, \ldots, C_{noc}$ denote each of the noc clusters consisting of $|C_1|, \ldots, |C_{noc}|$ members. Under this notation, the clustering process Cl is defined as the assignment of network nodes to groups of nodes (i.e. clusters):

$$Cl : \{1, \ldots, n\} \longrightarrow \{1, \ldots, noc\}$$

Nodes assigned to the same cluster are "similar" to each other and "dissimilar" to the nodes belonging to other clusters in terms of their packets requests per channel.

The notion of similarity is fundamental in a clustering process, and so far it is quite common to evaluate the dissimilarity between two items (in our case nodes) by using a distance measure [5]. To proceed with our network nodes' clustering process, the Squared Euclidean distance is employed which is a well-known and widely used distance measure in the vector-space model [5], [6]. Given that each node u_i is represented by the row i of the demand matrix D, this row is denoted as a multivariate vector consisting of w values as follows:

$$D(i,:) = (d(i,1), \ldots, d(i,w))$$

Therefore, the evaluation of the dissimilarity between two nodes can be expressed by the distance of their demand vectors. Therefore, $dist(u_x, u_y)$, where $u_x, u_y \in U$, denotes the Squared Euclidean distance of the nodes' demand vectors $D(x,:)$ and $D(y,:)$:

$$dist(u_x, u_y) = \|D(x,:) - D(y,:)\|^2$$

Consider an arbitrary cluster C_j, where $j = 1, \ldots, noc$, of the nodes' set U. The representation of cluster C_j when clustering process Cl is applied to it, collapses the nodes belonging to C_j into a single point (e.g. the mean value which does not correspond to an existing node). This point is called cluster's representative c_j (also known as centroid) since each node $u_i \in C_j$ is represented by c_j. Given the demand vectors of $u_i \in C_j$, the demand vector of c_j is defined as follows:

$$\textit{Means}(j,:) = \frac{1}{|C_j|} \sum_{u_i \in C_j} D(i,:), j = 1, \ldots, noc$$

Since both $D(i,:)$ and $\textit{MeansD}(j,:)$ are vectors, their dissimilarity is measured by their Squared Euclidean distance $dist(u_i, c_j)$. Considering all clusters, the *criterion function* J is defined to be the sum of distances over all channels between each node and the representative of the cluster that the node is assigned to:

$$J = \sum_{j=1}^{noc} \sum_{u_i \in C_j} dist(u_i, c_j)$$

Network nodes' clustering Cl aims at minimizing J

IV. The Proposed Node Clustering with Prioritized Scheduling

The core idea of the proposed NOC-PS is to handle real-time traffic based on nodes' clustering. In practice, it is a two-step process, where the network nodes are clustered according to their packets requests per channel and, then, they are scheduled based on the obtained clusters. The first step, namely the clustering step, is divided into two substeps, namely the nodes' clustering based on their high-priority packets (lines 1-3) and the nodes' clustering based on their low-priority packets (lines 4-6), respectively, as depicted in the flow control of Algorithm 1. The innovation introduced by NOC-PS is that high and low priority packets are clustered separately, with high-priority packets having the privilege of being scheduled prior to low-priority ones (line 7).

For the clustering process the K-means algorithm is employed which is a widely used partitional clustering algorithm [10]. The K-means minimizes the objective function J defined in Section III. During the clustering of nodes with high-priority packets i.e. D_h, the obtained clusters Cl_HP as well as the clusters' representatives table *Means_HP* are used in order to prioritize the clusters with long-length requests *SortedMeans_HP*. The calculated *SortedMeans_HP* is then used in order that the network nodes are rearranged. Once the *ClNodes_HP* is formed, the algorithm proceeds to the clustering of nodes with low-priority packets i.e. D_l. In a similar way, the nodes with low-priority packets are clustered and rearranged providing the *ClNodes_LP* service order. Given the *ClNodes_HP* and *ClNodes_LP*, NOC-PS proceeds to the scheduling step, where the logic of the OIS scheduling algorithm is used. During this step, the function *Schedule* forms the scheduling matrix S prioritizing the $ClNodes\_HP$ requests i.e. real-time traffic.

Algorithm 1 The NOC-PS flow control

Input: A set U of n nodes organized in two n x w demand matrices, namely the D_h of high-priority packets and the D_l of low-priority packets, the upper bound on nodes' requests k and the number of clusters noc.

Output: The scheduling matrix S.

*/*Clustering Step*/*

*/*Nodes' Clustering based on their high-priority packets*/*

1: $(Cl\_HP, Means\_HP) = K - means(D_h, noc)$
2: $SortedMeans\_HP = \textit{Quicksort}(Means\_HP)$
3: $ClNodes\_HP = \textit{Arrange}(SortedMeans\_HP)$ */*Nodes' Clustering based on their low-priority packets*/*
4: $(Cl\_LP, Means\_LP) = K - means(D_l, noc)$
5: $SortedMeans\_LP = \textit{Quicksort}(Means\_LP)$
6: $ClNodes\_LP = \textit{Arrange}(SortedMeans\_LP)$ */*Scheduling Step*/*
7: $S = \textit{Schedule}(ClNodes\_HP, ClNodes\_LP)$

The NOC-PS has time complexity $O(nkw^2)$. For the sake of brevity the proof is omitted.

A. A Numerical Example

This section provides a numerical example which illustrates the NOC-PS scheme thoroughly and compare its performance with POSA. POSA is not intended to handle real-time traffic. It is assumed a WDM star network consisting of $n = 6$ nodes and $w = 3$ channels. The set of nodes is $U = (u_1, u_2, u_3, u_4, u_5, u_6)$, the set of data channels is $\Lambda = (\lambda_1, \lambda_2, \lambda_3)$, while the upper bound of nodes' messages length is $k = 4$ packets. Given these parameters, the following 6×3 demand matrix D could represent the aggregate network traffic:

$$D = \begin{pmatrix} 2 & 1 & 2 \\ 1 & 1 & 1 \\ 1 & 4 & 3 \\ 3 & 4 & 3 \\ 0 & 2 & 2 \\ 2 & 2 & 3 \end{pmatrix}$$

while the following 6×3 demand matrices D_h and D_l could indicate the real-time and non-real-time traffic, respectively. Obviously, it holds that $D = D_h + D_l$, with high-priority packets i.e. D_h representing $25-30\%$ of the total or aggregate traffic i.e. D:

$$D = D_h + D_l = \begin{pmatrix} 0 & 0 & 1 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \\ 1 & 1 & 1 \\ 0 & 1 & 0 \\ 0 & 1 & 1 \end{pmatrix} + \begin{pmatrix} 2 & 1 & 1 \\ 0 & 1 & 0 \\ 1 & 3 & 2 \\ 2 & 3 & 2 \\ 0 & 1 & 2 \\ 2 & 1 & 2 \end{pmatrix}$$

Example 1: In the above demand matrices the fact that $D(3,2) = 4$ means that node u_3 requests four (4) packets on

TABLE II

THE SCHEDULING MATRIX S PRODUCED BY NOC-PS

	Timeslots															
	l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8	l_9	l_{10}	l_{11}	l_{12}	l_{13}	l_{14}	l_{15}	l_{16}
λ_1	$\mathbf{u_4}$	$\mathbf{u_2}$	u_3	u_4	u_4	u_1	u_1	u_6	u_6							
λ_2	$\mathbf{u_3}$	$\mathbf{u_4}$	$\mathbf{u_6}$	$\mathbf{u_5}$	u_3	u_3	u_3	u_4	u_4	u_4	u_1	u_1	u_5	u_6		
λ_3	$\mathbf{u_1}$	$\mathbf{u_3}$	$\mathbf{u_4}$	$\mathbf{u_6}$	$\mathbf{u_2}$	u_4	u_4	u_3	u_3	u_1	u_5	u_5			u_6	u_6

TABLE III

THE SCHEDULING MATRIX S PRODUCED BY POSA

	Timeslots																		
	l_1	l_2	l_3	l_4	l_5	l_6	l_7	l_8	l_9	l_{10}	l_{11}	l_{12}	l_{13}	l_{14}	l_{15}	l_{16}	l_{17}	l_{18}	l_{19}
λ_1	u_1	u_1	u_2	u_3	u_4	u_4	u_4	u_6	u_6										
λ_2	u_2		u_1		u_3	u_3	u_3	u_3	u_4	u_4	u_4	u_4	u_5	u_5	u_6	u_6			
λ_3		u_2		u_1	u_1	u_5	u_5		u_3	u_3	u_3		u_4	u_4	u_4		u_6	u_6	u_6

channel λ_2. One (1) out of these four (4) packets are of high-priority, since $D_h(3,2) = 1$, while the rest three (3) packets are of low-priority, since $D_l(3,2) = 3$. $\square$

Applying the K-means algorithm for $noc = 2$ in the above demand matrix of high-priority packets D_h results in $Cl\_HP = (2,1,2,2,1,2)$ which means that $u_2, u_5 \in C_1$, while $u_1, u_3, u_4, u_6 \in C_2$. Similarly, the nodes' clustering in terms of their low-priority packets results in $Cl\_LP = (2,2,1,1,2,2)$ which indicates that $u_3, u_4 \in C_1$, while $u_1, u_2, u_5, u_6 \in C_2$.

Given the Cl_HP clustering, the clusters centroids' demand matrix of high-priority packets *Means_HP* is formed according to the vectors of their clusters' members:

$$\textit{Means\_HP} = \begin{pmatrix} 0.5 & 0.5 & 0.5 \\ 0.25 & 0.75 & 1 \end{pmatrix}$$

while, based on the Cl_LP clustering, the clusters centroids' demand matrix of low-priority packets *Means_LP* is also formed according to the vectors of their clusters' members:

$$\textit{Means\_LP} = \begin{pmatrix} 1.5 & 3 & 2 \\ 1 & 1 & 1.25 \end{pmatrix}$$

Sorting *Means_HP* and *Means_LP*, according to the length of clusters' centroids, results in giving priority to C_2 over C_1 for high-priority packets, i.e. $SortedMeans\_HP = C_2, C_1$, and C_1 over C_2 for low-priority packets, i.e. $SortedMeans\_LP = C_1, C_2$. Therefore the NOC-PS schedules the high-priority packets of nodes u_1, u_3, u_4, u_6 prior to those of nodes u_2, u_5, i.e. $ClNodes\_HP = u_1, u_3, u_4, u_6, u_2, u_5$, and then, continues with the scheduling of low-priority packets as follows: $ClNodes\_LP = u_3, u_4, u_1, u_2, u_5, u_6$. On the other hand, POSA does not handle real-time traffic and, thus, it defines a sequential service order $u_1, u_2, u_3, u_4, u_5, u_6$ for the total packets of each node.

Table II and III depict the scheduling matrix S produced by NOC-PS and POSA respectively. Especially in Table II the packets of nodes (u_4, u_3, u_1), (u_2, u_4, u_3), (u_6, u_4), (u_5, u_6) and u_2 during the timeslot l_1, l_2, l_3, l_4 and l_5, respectively, represent the real-time traffic which is scheduled prior to the rest non-real-time traffic. Based on the above tables, the channel utilization providing by NOC-PS is 77% which is definitely improved in comparison with POSA, whose channel utilization is 65%. In terms of the mean packet delay of total traffic, the observed values are 6 timeslots for NOC-PS and 7.8 timeslots for POSA. However, the contribution of the proposed scheme is clearly depicted by the mean delay of high-priority packets, since NOC-PS cause mean delay of 1.5 timeslots, which is significantly improved in comparison with the 8.2 timeslots caused by POSA.

V. EXPERIMENTATION

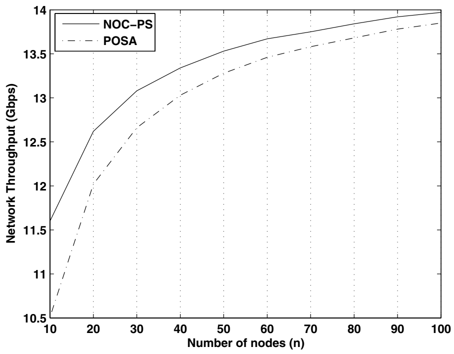
To evaluate the proposed algorithm we carried out experiments, where we compared NOC-PS with POSA. The performance of the compared algorithms is evaluated in terms of network throughput, mean packet delay and variance of delay. Network throughput represents the average number of bits transmitted per frame on each channel, while mean packet delay denotes the mean time in timeslots that packets are waiting at the queues till the beginning of their transmission. Variance of delay is another important performance metric, especially in the presence of real-time traffic, since it is crucial to keep the variance of delay of high-priority packets low, in order to avoid long delays.

Traffic modeling is based on two distinct models. According to the first model, it is assumed that the packet arrival process at each of the queues follows the Uniform distribution, while according to the second model, the packet arrival process is assumed that it follows the Poisson distribution $p(X;\theta) = e^{-\theta}\lambda^X/X!$. The second model proceeds to the generation of nodes load patterns defining three classes of nodes: light, medium or heavy according to their traffic load. The values of θ for these three classes are defined as $k/4$, $k/2$ and $3k/4$ [3], respectively, while each node is assigned to a class with equal probability.

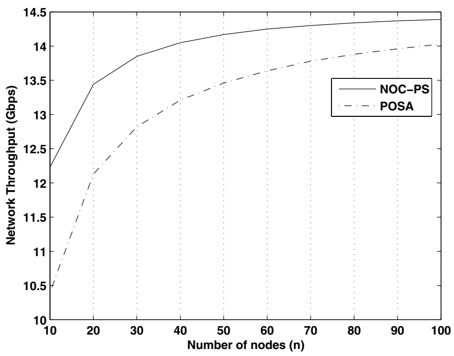
The simulation results are produced according to the following assumptions:

1) The line is defined at 3 Gbps per channel and the tuning time is considered to be negligible.
2) The outcome results from 10000 transmission frames.

Fig. 2(a) and 2(b) depict the network's throughput as a function of the number of nodes for $n = 10, 20, \ldots, 100$, while the number of channels is set to $w = 5$ and the number of clusters is fixed at $noc = 6$. The traffic load follows

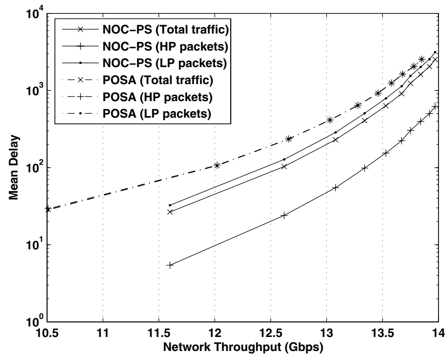


(a) Uniform model

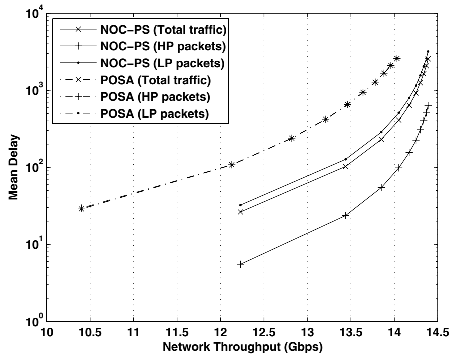


(b) Poisson model

Fig. 2. Network throughput as a function of the number of nodes for $w = 5$ channels, traffic load $k = \lfloor (n * w)/5 \rfloor$ and $noc = 6$ clusters.



(a) Uniform model



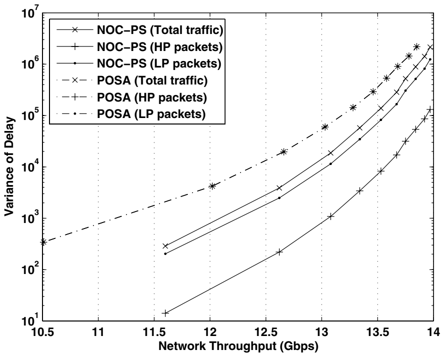
(b) Poisson model

Fig. 3. Mean packet delay of total traffic, high-priority and low-priority packets as a function of the network throughput.

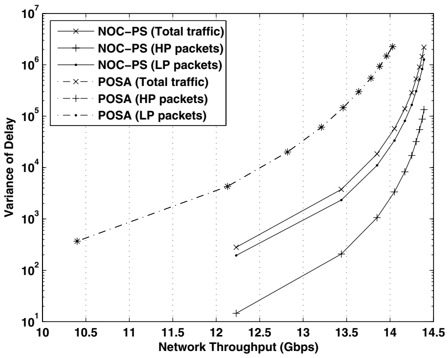
uniform and poisson distribution, respectively, where the upper bound of nodes' requests is $k = \lfloor (n * w)/5 \rfloor$ for scalability reasons [3]. The throughput improvement in case of the NOC-PS scheme indicates that the use of the proposed algorithm leads to a significant reduction of the schedule's length. It is apparent that for any number of nodes n, NOC-PS provides steadily higher throughput compared to POSA. This is due to the fact that NOC-PS apart from prioritizing the real-time traffic, it also provides to the long-length requests the privilege of being scheduled prior to the short-length ones and, thus, it allocates more free timeslots for the rest requests. Especially under poisson model NOC-PS exhibits better performance, since this model significantly differentiates the network's nodes and, thus, the clustering process succeeds in creating more coherent clusters (i.e. clusters with similar nodes). What is more, the clusters themselves are more dissimilar to each other and, thus, prioritizing those with heavy load advances the scheduling process. In practice, as the number of nodes increases from 10 to 100, the network's throughput provided by NOC-PS is from 9% down to 1% improved compared to the one of POSA under the uniform model and 15% down to 2.5% under the poisson model.

Mean packet delay is the second performance metric which is evaluated. In this part of experiments, Fig. 3(a) and 3(b) depict the mean delay of total traffic, high-priority and low-priority packets, as a function of the network throughput in case of uniform and poisson model, respectively, for the above values on network's parameters (i.e. n, w, k and noc). Based on these figures, it is observed that the curves depicting the mean packet delay of POSA for high- and low-priority packets are close to each other. This is due to the fact that POSA does not handle the packets' priority. On the other hand, the mean delay of high- and low-priority packets differ significantly under the NOC-PS scheme. It is important to mention that NOC-PS clearly outperforms POSA in terms of mean delay for both high and low priority packets. Especially in case of high-priority packets, the proposed NOC-PS scheme achieves a significantly lower delay in comparison to POSA, because such packets have the privilege of being scheduled prior to low-priority ones. Indicatively, as the number of nodes increases from 10 to 100, the mean delay of high-priority packets in case of NOC-PS is from 81% down to 75% lower than the corresponding mean delay of POSA for both uniform and poisson models. This significant improvement is not made in the cost of a high delay of low-priority packets, since as depicted in both Fig. 3(a) and Fig. 3(b) the low-priority packets' curves are very close to the total traffic curves.

Graphs, depicting the variance of delay for the NOC-PS and POSA schemes under prioritized real-time traffic, are given in Fig. 4(a) and 4(b). More specifically, the variance of delay of total traffic, high-priority and low-priority packets (for the above values on network's parameters), are depicted as a function of the network throughput in Fig. 4(a) and 4(b), when uniform and poisson models are employed, respectively. Both



(a) Uniform model



(b) Poisson model

Fig. 4. Variance of delay of total traffic, high-priority and low-priority packets as a function of the network throughput.

figures indicate that NOC-PS significantly reduces the variance of delay for all type of packets and especially for high-priority ones. In this case, as the number of nodes increases from 10 to 100, the variance of delay of high-priority packets in case of NOC-PS is from 96% down to 94% lower than the one of POSA for both uniform and poisson models. Furthermore, it is noticeable that in case of NOC-PS, the variance of delay of low-priority packets is lower than that of the total traffic and this is due to the fact that the proposed algorithm closely schedules packets of the same priority.

Overall, we can claim that for any number of nodes and under any traffic model, the proposed NOC-PS scheme is superior to POSA. This is due to the fact that NOC-PS is based on the clustering of the network's nodes which differentiates their service order taking into account both the specific nodes' demands and the priority information of their data packets.

VI. Conclusions

A novel scheduling scheme which combines clustering and prioritized scheduling techniques is introduced. The proposed NOC-PS scheme handles real-time traffic by providing to high-priority packets the privilege of being scheduled prior to low-priority ones. Furthermore, it is based on the rearrangement of the network's nodes service order by organizing them into clusters according to their packet requests per channel. Nodes with high and low priority packets are clustered and scheduled separately and, as result, the proposed scheme obtains significant throughput-delay improvements for real-time traffic, without, however, sacrificing the performance of non-real-time traffic.

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