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Quality Aware Deterministic Batch Scheduling Algorithm for Optimal Channel Utilization in Optical Burst Switching Networks

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Abstract

Most of the prominent Burst-scheduling programs put forward by different studies in the recent past emphasized on single bursts. A minor portion of programs have been designed to be capable of handling multiple bursts. Of these minor group of algorithms that can handle multiple bursts, the primary shortcoming faced by the authors is the procedure complicatedness. Further, the challenges associated with burst loss during the cluster development stage also remain key hurdle for these developers. This loss occurs because of outcome of standard timeslot procedures implemented in the development of burst clusters. This research work focuses on handling the above mentioned limitations and accordingly, a real-time quality-aware multiple burst scheduling through best possible paths in an OBS environment. This approach attempted to minimize burst loss and enhance a channel usage rate in the context of burst and channel cluster development, the suggested approach emphasized on cluster formation as hierarchies, which facilitate incremental upgrade. Consignment-level scheduling functions through differential emergence which evaluates the channel fit over different parameters of qualitative communication. Laboratory study outcomes confirm the advantages and efficiency of the suggested approach.

Keywords: OBS environment, burst loss, channel scheduling, individual consignment, online offline scheduling, incremental update, BFCA-VF

INTRODUCTION

OBS is an optic based network switching method which integrates the benefits of WR methods and optical networking methods [1], [2], [3], [4], [5]. The key benefits of the OBS are no additional requirement for buffering activities and e-processing at all nodes excluding sender and receiver nodes and the maximum channel usage rates observed in the OBS due to holding the optical path for only short durations. The primary switching component in this switching network is burst, often defined as a series of data packets being transmitted jointly from sender to receiver nodes and switching jointly even at the in-between nodes. The block of data or the burst includes two sub-components- header portion and the actual message portion. Of this, the first sub component is referred to as control-burst (CB) and is communicated detached from the message portion (DB). While CB is sent over a separate path to ensure adequate bandwidth path is booked for the associated DB transmission. Following certain time gap, DB message follows the CB through the channel pre-booked by the CB. This time gap between initiation of CB and DB is termed as burst-offset duration. This duration is always ensured to be same or more than the overall processing lag witnessed by the CB. Accordingly, this ensures that buffering time required during DB transmission at in-between nodes is waived off.

The function of resource booking of a CB at an intermediate node is usually a sub-component of scheduling sequence. Currently, two major methods of this channel scheduling are being used- online and offline methods [6], [7]. The online method involves a CB – upon reaching a main node, requests for booking the nodes and channel for transmitting its associated DB. On the other hand, offline method involves the BCPs reaching within a timeframe at a node, schedule all their bursts at a time through either of these programs- OBS-GS [8], MWIS-OS [9], LGS [10], heuristics [11], Greedy OPT [12], BATCHOPT [12], or LGS-MC [13].

As depicted in [11], [12], [13], batch scheduling is highly efficient compared to online method but the batch process needs further upgrade functions. Accordingly, the second approach involves higher complexity compared to the first method.

RELATED RESEARCH

Several scheduling programs were put forward in this context and these can be broadly grouped into two classes- online and offline programs. In the primary methods, every reaching BHP requests a program to book instantly the required channels and nodes for the associated burst. On the other hand, in the offline or bulk method, the BHPs reaching within timeframe will request for scheduling their messages in parallel [14], [15].

The challenge of optimal batch scheduling can be translated into detecting a huge independent cluster (MWIS-OS is considered as the maximum weighted cluster) in the interval chart. Nevertheless, the complicatedness of this method is Np-complete [16].

A batch scheduling method for multiple-paths with the assistance of complete wavelength converters was put forward in the study in [17], termed as Greedy OPT. These observations depict that it possesses linear complicatedness (O (MN)) and an efficient missing information rates, but it is yet to be optimal because of the first-fit concept.

The challenge of batch scheduling that is associated to bursts reaching within a timeframe over multiple paths, can be designed as a job-scheduling task, and an interval chart can be built to design the most desired scheduling resolution [18]. Similar to job-scheduling, the batch scheduling of bursts within a given timeframe is related with the task of scheduling with S-NIMs due to the fact that there can be a burst which doesn't set into the schedule for some specific information path if its initiation time is prior to the recent free unscheduled time of the path being considered.

Due to the NP-hard complicatedness of these S-NIM machines [18], it is feasible to utilize heuristic techniques [11] or to shift the issue from S-NIM to scheduling with similar ones (S-IM) [18].

A different program for batch scheduling, termed LGS-MC [13], also proposed an almost ideal scheduling outcome. Aiming to attain the best possible scheduling of all transmission paths, the model attempts to optimize batch scheduling over all paths. As can be understood, this method involves most efficient scheduling but also involves complexity. However, the complexity of this model is much lower than other benchmark methods [12].

Quality Aware Deterministic Group Scheduling Program

This section presents the sequence of burst scheduling in the context of deterministic group sequencing program. This model is an extension to our earlier contribution DBSA [19] that performs the establishment of groups corresponding to paths with relative likeliness with their respective initiation time of unoccupied duration, development of groups corresponding to paths with relative likeliness with their respective arrival duration and also has strong correlation among these groups with regard to bursts and paths. Later, it schedules the paths available in the group to the bursts available in the corresponding group, which correlates using differential evolution that assesses fitness of the correlated burst and channel, which is on the basis of transmission quality factors, proposed in our previous research work [11]. In addition, the sub chapters detail all these sequences involved in the proposed method.

Grouping transmission paths and Bursts

For grouping the transmission paths, the proximity between the initiation of unoccupied time of the paths accounted in fitness objective of the grouping sequence implemented. All groups are presented through the pairs of transmission paths which overlap about their unoccupied duration. The grouping sequence identifies the unoccupied transmission paths as separate groups on the basis of their initiation time and completion of the unoccupied time so that those paths that overlap during the unoccupied time are regarded as same group. In the same process, the bursts are clustered so that any cluster includes pair of bursts which overlap during the same duration between arrival time and needed communication duration. But the bursts continue to stream with scheduler on an increasing arrival duration basis and the new unoccupied durations of the transmission paths also sync with this increasing initiation time, and accordingly, the group establishment procedure suggested is a progressive model, which neutralizes the burst loss and inappropriate path scheduling, which are important challenges in available literature [12]. Nevertheless, on contrary to k-means algorithm, the suggested model does not limit the group number in advance. This procedure is compulsorily attuned to time-series transmission information, so that the recently reached data corresponds to either the recent established group or establishes a new group that integrates with the next set of data set to flow. The total procedure of grouping transmission paths as well as grouping of bursts is presented in the below sub-chapters.

1) Grouping the transmission paths

The sequences included in the procedure of grouping the transmission paths as diverse clusters are presented below:

- Sort the unoccupied paths in increasing degree of their initiation of the unoccupied time duration, so that the path which permits to sit idle initially will be given first priority and subsequently next transmission paths on the same concept.
- Choose the first transmission path c_1 from the sorted order according to the centroid of the group ccl_1,
- Shift these paths from the list in increasing sequence to the group, so that the initiation of the unoccupied time duration of the chooses path is smaller than the

completion of the unoccupied time duration of the interval of ccl_1.

- Choose the transmission path from the group ccl_1, which is consisting highest unoccupied period as new ccl_1 and choose the path from the list so that the chosen paths possess initiation of their unoccupied time period is lower than the completion of unoccupied time duration of ccl_1.
- In case the paths in the group ccl_1 remain same when compared to the paths in that group having earlier, then finalize the group as the last one.
- Iterate the aforementioned sequences till such time that no unoccupied transmission paths are observed in the sorted list.

The sequence of steps to group the unoccupied channels is presented in the following table:

Table 1: Algorithm to Cluster the Idle Channels

Let the notation $ICL = \{c_1, c_2, c_3, ...c_n\}$ as list of idle channels that are sorted in ascending order of their start of the idle time interval, such that start time $s(c_i)$ of idle time interval of channel c_i must less than or equal to the start time $s(c_{i+1})$ of idle time interval of channel c_{i+1}.

Let the notation $iti(c_i)$ is the end time of the idle time interval of the channel c_i.

step 1: $j = 1$ //counter j initialized to 1

step 2: ccl_j //an empty set representing j^{th} cluster

step 3: $tccl$ // an empty set

step 4: $c(ccl_j) = c_1$ // channel c_1 is considered as the initial centroid $c(ccl_k)$ of the cluster ccl_k

step 5: $\forall_{i=1}^{|ICL|} \{c_i \exists c_i \in ICL\}$ Begin

step 6: $if\left(s(c_i) < \left(s(c_j) + iti(c_j)\right)\right)$ Begin

step 7: $ccl_j \leftarrow c_i$

step 8: End // of step 6

step 9: Else go to step 11

step 10: End // of step 5

step 11: $if(ccl_j <> tccl)$ begin

step 12: $miti = 0$

step 13: $\forall_{p=1}^{|ccl_j|} \{c_p \exists c_p \in ccl_j\}$ begin

step 14: $if\left((s(c_p) + iti(c_p)) > miti\right)$ begin

step 15: $miti = s(c_p) + iti(c_p)$

step 16: $c(ccl_j) = c_p$

step 17: End // of step 14

step 18: End // of step 13

step 19: $tccl \leftarrow \phi$ // empty the set $tccl$

step 20: $tccl \leftarrow ccl_j$ // clone the cluster ccl_j

step 21: $ccl_j \leftarrow \phi$ // empty the cluster set

step 22: Go to step 5

step 23: End // of step 11

step 24: Else Begin // of condition in step 11

step 25: Finalize the cluster ccl_j

step 26: $ICL \setminus ccl_j$ \\ prunes the entries of the j^{th} cluster from ICL, and index of rest of the channels in ICL starts from one.

step 27: $if(|ICL| > 0)$ begin

step 28: $j++$

step 29: $tccl \leftarrow \phi$

step 30: $c(ccl_j) \leftarrow \{c_1 \exists c_1 \in ICL\}$

step 31: Go to step 5

step 32: End // of step 27

step 33: End // of step 24

2) Grouping the Bursts

In addition, the bursts which reach the scheduler and are awaiting at it attempt to become part of groups or establishes new groups so that each of these groups hold the burst which are overlapping on necessary communication period. These sequences are same to the aforementioned method followed for grouping the transmission paths with unoccupied time periods.

The sequences included in the procedure of grouping the bursts waiting at the scheduler as diverse clusters are presented below:

- Sort the awaiting and arriving bursts in increasing sequence of their reaching time, so that the bursts are sequenced according to their reaching time
- Choose the burst b_1 which is listed before others in the

above list as centroid of the group bcl_1,

- Shift the bursts according to their sorted order to the group bcl_1 provided if the reaching time of such bursts is overlapping with communication duration of the centroid of the respective group.
- Later choose theburst from the group, which possesses highest transmission completion period as new centroid and rebuild the group bcl_1, so that this group consists of bursts which have reaching time and that is overlapping with the communication duration of the bcl_1
- In case the bursts in the group bcl_1 remain same when compared to the bursts in that group with earlier centroid, then finalize the group as the last one.
- Iterate the aforementioned sequences till such time that no bursts are observed in the sorted list

The sequence of steps for grouping the bursts is same as the process presented in above table, which incorporates waiting bursts list BBL in place of unoccupied transmission paths list ICL. Further, in place of path unoccupied duration commencement time $s(c)$, burst reaching or arrival time $a(b)$ is used. Similarly, in place of unoccupied duration $iti(c)$ of the transmission path, necessary burst transmission period $rtt(b)$ is used. The sequence of steps to group bursts is presented in the table below (both the tables almost depict same flows).

Table 2: The Algorithm to Cluster the Bursts

Let the notation $BBL = \{b_1, b_2, b_3, ..., b_n\}$ as list of bursts those sorted in ascending order of their arrival time, such that arrival time of burst b_i must less than or equal to the arrival time of burst b_{i+1}.

Let the notation $rtt(b_i)$ is the required transmission time of the burst b_i.

step 1: $j = 1$ //counter j initialized to 1

step 2: bcl_j //an empty set representing j^{th} cluster

step 3: $tbcl$ // an empty set

step 4: $c(bcl_j) = \{b_1 \exists b_1 \in BBL\}$ // burst b_1 is considered as the initial centroid $c(bcl_j)$ of the cluster bcl_j

step 5: $\forall_{i=1}^{|BBL|} \{b_i \exists b_i \in BBL\}$ Begin

step 6: $if\left(a(b_i) < \left(a(b_j) + rtt(b_j)\right)\right)$ Begin

step 7: $bcl_j \leftarrow b_i$

step 8: End // of step 6

step 9: Else go to step 11

step 10: End // of step 5

step 11: $if(bcl_j <> tbcl)$ begin

step 12: $mrtt = 0$

step 13: $\forall_{p=1}^{|bcl_j|} \{b_p \exists b_p \in bcl_j\}$ begin

step 14: $if\left((a(b_p) + rtt(b_p)) > mrtt\right)$ begin

step 15: $mrtt = a(b_p) + rtt(b_p)$

step 16: $c(bcl_j) = b_p$

step 17: End // of step 14

step 18: End // of step 13

step 19: $tbcl \leftarrow \phi$ // empty the set $tbcl$

step 20: $tbcl \leftarrow bcl_j$ // clone the cluster bcl_j

step 21: $bcl_j \leftarrow \phi$ // empty the cluster set

step 22: Go to step 5

step 23: End // of step 11

step 24: Else Begin // of condition in step 11

step 25: Finalize the cluster bcl_j

step 26: $BBL \setminus bcl_j$ \\ prunes the entries of the j^{th} cluster from BBL, and index of rest of the bursts in BBL starts from one.

step 27: $if(|BBL| > 0)$ begin

step 28: $j{+}{+}$

step 29: $tbcl \leftarrow \phi$

step 30: $c(bcl_j) \leftarrow \{b_1 \exists b_1 \in BBL\}$

step 31: Go to step 5

step 32: End // of step 27

step 33: End // of step 24

3) Correlating the burst groups and transmission path groups

This chapter presents the procedure for establishing correlation between the bursts group with that the unoccupied transmission path group. The basis on which the correlation is developed is that every group implying the bursts to respective group of paths by predicting the possibility of three criteria. The criteria include-

- The proximity of the lowest reaching time of the bursts in the group and the lowest initiation time of the paths in the respective group

- The proximity of the mean transmission duration needed for bursts depicted by the chooses group and the mean unoccupied duration of the paths in respective group
- Further, the proximity of deviations spread among communication durations of all the bursts in the group and the mean deviation spread between unoccupied durations of the transmission paths in the respective group.

To determine the extent of correlation between bursts group and the groups of unoccupied transmission paths,

Order the burst groups in decreasing sequence of the lowest reaching time of the related groups and order then so that index of every group in the ordered list turns out to be their rank associated with their lowest reaching time. These indexes are depicted as reaching time ranks in next paragraphs.

Similarly, order the path groups in decreasing sequence of their unoccupied initiation time and order then so that the index in the ordered list as the rank of respective group. These indexes are depicted as unoccupied interval initiation time rank in the next paragraphs.

Later, order the burst groups in decreasing sequence of their mean communication duration needed to send bursts in respective sequence. Rank the groups, so that the index of every group in the order turns out to be the rank associated to its mean communication duration needed. These indexes are depicted as needed communication duration rank in the next paragraphs. Similarly, order the path groups in decreasing sequence of their mean unoccupied time and rank these groups, so that their index in the sorted list as the rank of respective group, that is depicted as unoccupied interval rank in the next paragraphs.

In addition, the burst groups must be sequenced in decreasing flow of deviation identified between needed communication time of bursts in groups, which are depicted as communication-duration deviation ranks. Further, allocate ranks to the unoccupied transmission path groups in decreasing sequence of deviation spread between unoccupied intervals of the paths in corresponding groups, which are depicted as unoccupied interval deviation rank.

Following this stage, the proximity of burst groups and path groups is established, which involves the proximity of reaching time rank allocated to the burst group and the unoccupied path's interval initiation time tank of the path groups, proximity of communication time rank and unoccupied duration rank, and the proximity of communication deviation rank and interval deviation rank.

Later, the best possible path group associated to a burst group is identified that utilizes the proximity calculated between ranks allocated to these groups on basis of different parameters discussed above. The sequence of steps involved in allocating ranks to the burst groups is presented in the following table and the procedure of allocating ranks to the path groups is also similar but in place of burst groups BCL, the path group CCL is substituted.

Table 3: The Algorithm that Defines the Discriminative Ranks for Burst Clusters

step 1: Let the notation $BCL = \{bcl_1, bcl_2, ..., bcl_n\}$ denotes the list of n burst clusters
step 2: $TBCL \leftarrow BCL$ // clone the set BCL as $TBCL$
step 3: $loBCL$ // is an empty set contains the burst clusters in descending order of their least arrival time
step 4: $toBCL$ //is an empty set contains the burst clusters in descending order of their average of required transmission time
step 5: $doBCL$ // an empty set contains burst clusters in ascending order of the deviation spanned over the bursts in the corresponding clusters.
step 6: $idx = 0$
step 7: While ($(\vert TBCL\vert > idx)$ do // while $TBCL$ is not empty
step 8: $lb = \{bcl_i \exists bcl_i \in TBCL \wedge 0 < i < \vert TBCL\vert \wedge bcl_i \notin loBCL\}$
step 9: $tb = \{bcl_i \exists bcl_i \in TBCL \wedge 0 < i < \vert TBCL\vert \wedge bcl_i \notin toBCL\}$
step 10: $db = \{bcl_i \exists bcl_i \in TBCL \wedge 0 < i < \vert TBCL\vert \wedge bcl_i \notin doBCL\}$
step 11: $ridx = 1$ // index counter
step 12: $\forall_{j=1}^{\vert TBCL\vert} \{bcl_j \exists bcl_j \in TBCL\}$ do
step 13: $if\left((bcl_j \neq lb) \& bcl_j \notin loBCL \& (lat(bcl_j) > lat(lb))\right)$ do
step 14: $lb \leftarrow bcl_j$
step 15: End // of step 13
step 16: $if\left((bcl_j \neq tb) \& bcl_j \notin toBCL \& (tt(bcl_j) > tt(tb))\right)$ do
step 17: $tb \leftarrow bcl_j$
step 18: End // of step 16
step 19: $if \begin{pmatrix} (bcl_j \neq db) \& \\ bcl_j \notin doBCL \& \\ (rmsd(bcl_j) > rmsd(db)) \end{pmatrix}$ do
step 20: $db \leftarrow bcl_j$
step 21: End // of step 19
step 22: End / of step 12
step 23: $r_{lat}(lb) = ridx$ //rank assigned to burst cluster, which is in the order of least arrival time.
step 24: $loBCL \leftarrow lb$
step 25: $r_{tt}(tb) = ridx$ //rank assigned to burst cluster, which

is in the order of average transmission time.

step 26: $toBCL \leftarrow tb$

step 27: $r_{rmsd}(db) = ridx$ //rank assigned to burst cluster, which is in the order of deviation spanned over the transmission time of the bursts of corresponding cluster.

step 28: $doBCL \leftarrow db$

step 29: $ridx += 1$

step 30: $idx += 1$

step 31: End //of step 7

4) Associating burst and transmission path groups

The next stage of the suggested approach involves establishing correlation of the burst groups with transmission path groups through differentiated ranks allocated in the previous stages depicted in the above two tables. The correlation parameters to bind both the groups and the sequence of steps is depicted below-

For the considered burst group bcl, a transmission path group ccl will be bind so that the rank

- $r_{ii}(ccl)$ allocated to transmission path groupin the mean unoccupied period is more than or same as the rank $r_{tt}(bcl)$ allocated to burst group below the mean communication duration $(r_{ii}(ccl) \geq r_{tt}(bcl))$,
- $r_{rmsd}(ccl)$ allocated to transmission path group below deviation spread across unoccupied duration of the transmission paths of the respective group ccl is smaller than or same as the rank $r_{rmsd}(bcl)$ allocated to burst group below deviation spread across communication duration of the bursts present in the group bcl $(r_{rmsd}(ccl) \leq r_{rmsd}(bcl))$,
- $r_{lst}(ccl)$ allocated to transmission path group ccl below the lowest initiation time of the unoccupied duration is almost same as the rank $r_{lat}(bcl)$ allocated to the burst group bcl below the lowest reaching time $(r_{lst}(ccl) \cong r_{lat}(bcl))$

A. Scheduling bursts over transmission paths for associated groups

Having established the correlation between two groups, the suggested approach schedules the burst present in the group bcl through the transmission paths identified in the group ccl, which are allocated to the burst group bcl on the basis of discriminative ranking approach. This scheduling approach involves the concept of differential-evolution approach, which associates every single burst with the optimal transmission path. With respect to this, the DE [20] method evaluates the fit between burst and transmission path using different parameters corresponding to the path quality. The prominent metrics employed for this purpose have been selected based on our previous research work [21]. The next sub-chapters present a detailed analysis of the parameters incorporated and the sequence of steps involved in executing DE algorithm to achieve optimal scheduling of all the bursts present.

A. DE scheduling approach

Several approaches have been put forward for allocating optimal transmission paths for data packets in the contemporary literature. Of these approaches, DE strategy [20] is regarded as the most preferred approach for achieving universal optimization.

The functioning of this algorithm is almost same as the functioning of GA algorithm [22]. The basic difference between the two models is that in GA, t value varies with respect to operating with new genotypes. Both the parent and child chromosomes are assessed with respect to their fit to the proposed model and if the later ones are observed to have high fit value, it remains and the other group is disregarded. The vice-versa also remains true in the context. The fittest child substitutes the related parent.

The differentiated fitness processes and multiple cross-over approaches incorporated in DE algorithm marks the disparity between various DE strategies available in existing studies [23], [24], [25], [26]. One of the new DE approaches that is efficient in this context has been put forward in the contemporary study [27].

B. Quality Assessment Parameters Employed in Fitness Establishment

- Extent of Rescheduling (negative): The rescheduling possibility is a negative parameter and accordingly, minimum value is preferred. The parameter denotes the mean of burst re-scheduling needed for first scheduled to a given transmission path. Mathematically, the parameter is computed on the basis of the below equation-

$$crs(c_i) = \frac{crc(c_i)}{csc(c_i)} \quad \ldots\ldots(3)$$

  - In the eq (3), $crs(c_i)$ denotes the possibility of rescheduling of the transmission path c_i; The numerator $crc(c_i)$ implies the count of previous rescheduling, and the denominator $csc(c_i)$ depicts the original count of the transmission path c_i is scheduled.

- Extent of Obstruction (negative): The obstruction possibility is also a negative parameter and accordingly, minimum value is preferred. The parameter depicts the chances of obstruction occurrence in the transmission path arousing because of abnormal path usage. Mathematically, the parameter is computed on the basis of the below equation-

$$os(c_i) = \frac{ooc(c_i)}{\csc(c_i)} \quad \text{……..(4)}$$

- In the eq (4), the computed value $os(c_i)$ denotes the possibility of obstruction occurrence in the transmission path c_i; the numerator $ooc(c_i)$ depicts the number of obstructions computed in previous schedules and the denominator refers to the original count of obstructions.

- Transmission Path possession time intervene scope (negative): Holding the transmission path for longer periods is also not preferred and accordingly, the minimum the value, the best. The parameter depicts the extent of a transmission path being impacted by time-lapse when being utilized by secondary users. Mathematically, the parameter is computed on the basis of the below equation-

$$ptis(c_i) = \frac{ptic(c_i)}{\csc(c_i)} \quad \text{……(5)}$$

  - In the eq (5), the computed value $ptis(c_i)$ denotes the possession time possibility, the numerator $ptic(c_i)$ is the count in previous scheduling and the denominator refers to count in actual scheduling.

- Extent of transmission path usage (positive): The higher the value of utilization, the better the performance of the model. Accordingly, maximum values for this parameter are preferred. Mathematically, the parameter is computed on the basis of the below equation-

$$cus(c_i) = \frac{cuc(c_i)}{\csc(c_i)} \quad \text{…… (7)}$$

  - In the eq (7), the computed value $cus(c_i)$ denotes the extent of using the given transmission path c_i; the numerator $cuc(c_i)$ denotes the count of successful path usage in earlier scheduling and the denominator refers to the usage in current scheduling.

- Availability of Bandwidth compatibility (positive or negative): Compatibility of a path bandwidth is the basic QoS parameter, because adequate bandwidth is the primary requirement to execute burst communication with some least assurance. This can either turn out to be desirable or undesirable parameter. The amount of bandwidth accessible over a path should be more than or at least equal to the necessary value of the existing burst to be scheduled and should not cross the total of the value needed for current burst and preset threshold value. In case the bandwidth is smaller than the necessary value or alternatively, if it is more than the total of needed bandwidth and threshold value this parameter turns out to be undesirable. If the available bandwidth is in between these extremes, the parameter turns out to be desirable parameter. Mathematically, the parameter is computed on the basis of the below equation-

$$bc(c_i) = ba(c_i) - br(c_i) \quad \text{…… (8)}$$

  - In the eq (8), $bc(c_i)$ depicts the bandwidth capacity of the transmission path c_i, $ba(c_i)$ depicts the bandwidth accessible at the transmission path c_i and the '$br(c_i)$' denotes the bandwidth necessary at c_i for the present burst sequencing.
  - The value of $bc(c_i)$ should be smaller than the preset threshold level rbt, because $bc(c_i) > rbt$ implies that the path c_i is already overfilled for present bandwidth necessity that can be held for next scheduling with larger necessity.

- Extent of Inactive Duration (positive or negative): The inactive duration of the transmission path should b larger than the overall transmission duration needed for the actual burst scheduling and failing which, the path becomes unsuitable for scheduling. Accordingly, the metric is also a basic QoS parameter and based on the value, the parameter can be desired or undesired. This is because the inactive duration should be larger than transmission duration but at the same time, it should not exceed the total needed transmission duration plus the preset threshold value $rttt$. If the computed value falls within these two extreme limits, it is regarded as desirable parameter and if it falls either below the range or exceeds the range, it turns out to be negative parameter. Mathematically, the parameter is computed on the basis of the below equation-

$$citfs(c_i) = citf(c_i) - rct(c_i) \quad \text{…… (9)}$$

  - In the eq (9), the computed value $citfs(c_i)$ denotes the extent of inactive duration of the respective transmission path c_i, the $citf(c_i)$ denotes the present accessible inactive duration of the c_i and $rct(c_i)$ refers to the necessary path duration for transmission of the current burst.
  - If $cifts(c_i) \leq 0$, then c_i is unsuitable for transmission.
  - If $cifts(c_i) > 0 \,\&\, cifts(c_i) \leq rttt$ then the path will be regarded as suitable for transmission

- If $cifts(c_i) > rttt$ then the path is unsuitable for transmission, because the value $cifts(c_i) > rttt$ implies that the path is already overfilled for the present burst sequencing towards accessible inactive duration, as it can be held for next schedules, which need larger path inactive durations.

C. The Fitness Task

For establishing the fitness of the channels, we consider the following QoS parameters-

Extent of Path pre-emption, Extent of re-scheduling, Extent of obstruction, Extent of path possession duration, Extent of abandonment, Extent of Path usage, extent of bandwidth accessibility, extent of inactive duration

$$M = \{[cps(c_i), crs(c_i), os(c_i), ptis(c_i), ds(c_i), cus(c_i), bc(c_i), citfs(c_i)] \forall i = 1...x\}$$ thatare for the accessible transmission paths $C = \{c_1, c_2, ...c_x\}$ considered for scheduler s_j

Of the above parameters, $bc(c_i), citfs(c_i)$ are basic parameters are employed to compute the basic score of every path.The transmission paths are sequenced according to the score computed through these parameters. The QoS parameters of the paths are classified as either desirable or undesirable parameters as discussed in the above sub-chapter. In case the increasing value of the parameters are observed to be the desired values, then the parameters are referred to as desirable ones and if the decreasing values of the parameters are observed to be the desired values, then the parameters are referred to as undesirable ones.

Accordingly, the desirable and undesirable parameters should be normalized, which is accomplished through the following sequences:

For each channel $[c_i \exists c_i \in C]$ begin

For each metric $[m_k \forall m_k \in M]$ Begin

// here M represents values of selected metrics of channel c_i of scheduler s_j

If m_k is value of positive metric then $m_k = 1 - \frac{1}{m_k}$

Else If m_k is value of negative metric then $m_k = \frac{1}{m_k}$

End

End

Then find the principle score as follows:

$$ps(c_i) = 1 - (bc(c_i) \otimes citfs(c_i))$$

In this equation, $pc(c_i)$ denotes the principle value of the path c_i, $(bc(c_i) \otimes citfs(c_i))$ is the multiplication of normalized scores $(0 < \{bc(c_i), citfs(c_i)\} < 1)$, which is the multiplied value of fractions. Accordingly, to achieve the increasing value of the principle score, this multiplied value is subtracted from 1.

Later, the accessible paths are sequenced according to their principle scores and normalized scores in a descending order, so that all paths are assigned dissimilar ranks for diverse parameters. Further, these ranking values are utilized as feeding parameters to the scheduling model, which computes the QoS discrepancy affect qdi.

Let rank set of a channel $[c_i \exists c_i \in C]$ is

$$R(c_i) = [rcps(c_i), rcrs(c_i), ros(c_i), rptis(c_i), rds(c_i), rcus(c_i), rbc(c_i), rcitfs(c_i)],$$

then QoS discrepancy impact (qdi) of each channel can be measured as follows.

$$\mu_{R(c_i)} = \frac{\sum_{j=1}^{|R(c_i)|} [m_j \forall m_j \in R(c_i)]}{|R(c_i)|} \quad .....(10)$$

// the above equation represents the average of the ranks obtained for different metrics of channel c_i

$$qdi(c_i) = \left[\frac{\sqrt{\left(\sum_{k=1}^{|R(c_i)|} (\mu_{R(c_i)} - [m_k \forall m_k \in R(c_i)]) \right)^2}}{|R(c_i)|} \right]^{-1} \quad ...11)$$

The eq (11) is extracted from the sequence of computing variance between the fixed count of feature values. In the equation, $\mu_{R(c_i)}$ denotes the average of all ranks of QoS parameters of the transmission path c_i.

D. DE strategy based Transmission Path Allotment

For all groups related to bursts and the groups related to paths, map each of the burst to a path from the list of paths ordered as discussed in above sub-chapter. These are depicted as chromosomes, which are fed as inputs to DE strategy. In the next phases, it chooses a set of chromosomes and executes mutation function so that bursts estimated in each of the chosen chromosomes shall exchange their mapped paths. In case newly established sets are observed to be in fit when measured up against parent chromosomes, then the newly established sets prevail and the parents are disregarded. Alternatively, if the newly established sets don't prove to be fit, the parents will prevail and these sets will be disregarded. The process of fitness evaluation is executed in the sequence of steps presented in the sub-chapter 3.2.3.

Simulation Setup And Observations

Analysis of the simulation outcomes of the proposed model are presented in this chapter. The NSF network topology has been used for simulating the model where 38 users were selected for single mode communication in a bi-mode environment employing JAVOBS [13]. An average data message volume of 64 bytes has been considered and all together, 1024 packets are framed for each burst volume. These packets are ensured to possess different quantities, different durations and different bandwidth requirements to ensure the experiment reflects real-time scenario. The mean experimentation duration is fixed at 600 seconds for the implementation. Testing executed for the suggested approach of DBSA and other standard approaches is referred to as LGS-MC [10].

Efficiency evaluation of the suggested approach involved the following evaluation parameters-

a. Burst loss rate in the context of fluctuating loadsize and standard duration

b. Burst loss rate in the context of standard load and fluctuating duration

c. Path usage rate in the context of fluctuating load size and standard duration

d. Path usage rate in the context of standard load size and fluctuating duration

e. Mean scheduling duration, which is between 10 and 90; duration set between 10 μs and 50 μs

A. Efficiency Analysis

Experimental outcomes successfully demonstrate that the proposed QDBSA approach recorded superior performance over the other state-of-the-art scheduling approaches DBSA, and LGS-MC selected for comparison. Related to the changing efficiency parameters considered, QDBSA posed superior performance over the other approach regarded for the comparison. The Bust-loss rate for various bursts possessing standard duration of $(35\mu s)$ presented in the Figure 1 exhibits that the QDBSA approach is 13.5%, and 2% smaller than the values recorded in LGS-MC approach and DBSA approach respectively.

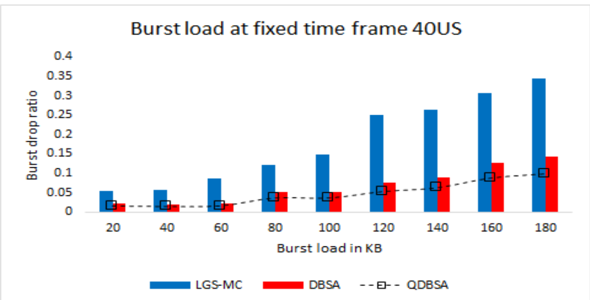


Figure1: Burst Drop ratio against varied burst load and constant timeframe

The burst-loss rate in the context of varying durations and standard burst volume at 120 kilo bytes has yielded 21%, and 5.8%additional burst lossfor LGS-MC, and DBSA over the proposed model QDBSA as can be observed in the chart below (Figure 2).

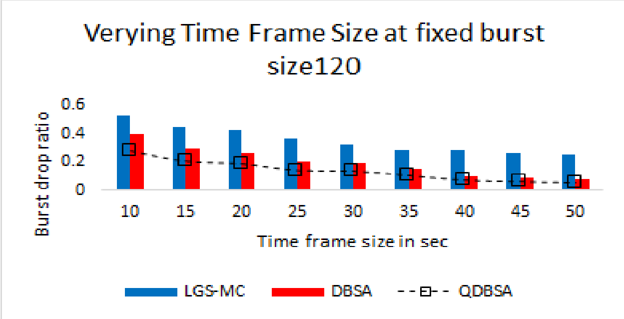
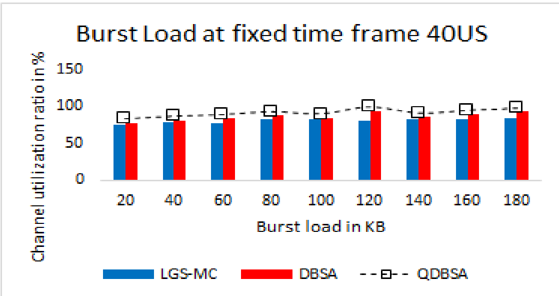
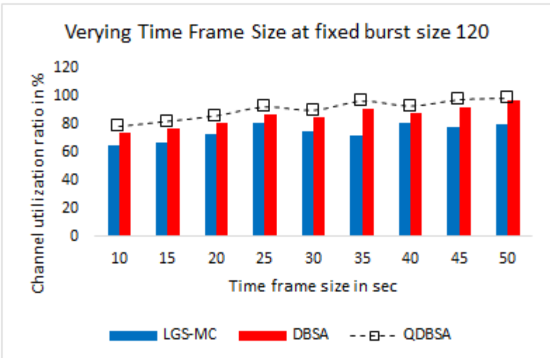


Figure2: Graphical representation of Burst Drop Ratio against volatile timeframes and constant burst size

The usage rate of channel as transmission path reflected for the proposed approach QDBSA is 11.6%, and 5.4% larger than the usage rate of channel as transmission path that observed for LGS-MC, and DBSA respectively, which is perceived for fluctuating burst size, and standard duration (35 μs). Similarly, in the case of standard burst size (120kb), and fluctuating duration, the proposed model QDBSA recorded 17%, and 5% superior performance over the LGS-MC, and DBSA. The comparative performances of these models are depicted in the charts below (Figure 3).



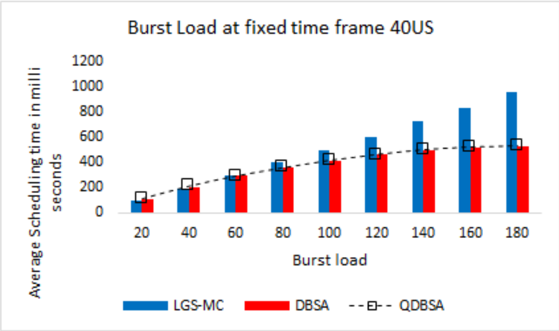
(a) Under volatile burst load with constant timeframe



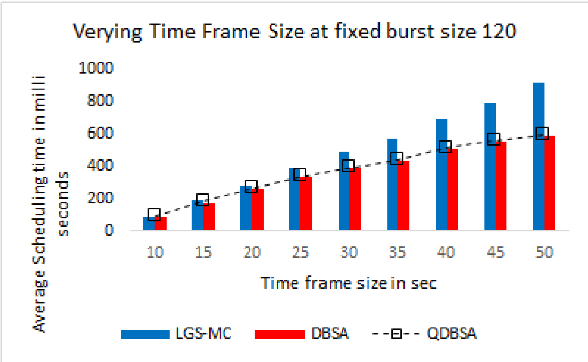
(b) Under constant burst load with volatile timeframe

Figure3: Graphical Representation of Channel utilization ratio

Analysing the charts below (Figure 4), we can understand that the process time analyzed for the benchmark model QDBSA is 23% less than the other model LGS-MC, and 2% more than the other model DBSA, which is almost similar in both the contexts- ‘fluctuating load size- standard duration (35 μs)’ and ‘standard load size (120kb)- fluctuating duration’.



(a) Volatile burst loads with constant timeframe



(b) Constant burst load with volatile timeframes

Figure 4: Graphical Representation of Average time to schedule bursts

The mean duration required are potentially similar to schedule in both the contexts, with fluctuating load sizes and standard duration of 35 μs , fluctuating durations with standard load 120kb. In both the instances, the proposed model has superior performance as compared to the other benchmark approaches.

CONCLUSION

The research work put forward a batch burst scheduling approach, referred to as ‘QDBSA algorithm’ for best possible path usage in OBS based networks. The main aim of the study has been to achieve optimal transmission path usage together with lowest burst loss rate and highest throughput. The suggested approach sequences the bursts under clusters and each of these clusters is further ordered in a 3-phase hierarchy. Differentiated ranking approach is used to accomplish this sequencing. In addition, the bursts belonging to a cluster are sequenced through quality aware unoccupied transmission paths detected in the respective path group that associates. This procedure involves Differential Evolution approach that assesses the possible transmission quality as fitness of the burst and channel association. The quality metrics used in this regard were presented in our previous research work [11]. Differing from other existing approaches like LGS-MC [10], DBSA [19] regarded for assessment of the performance of the proposed approach, the proposed approach reduced the complexity in scheduling. It also enhances the chances of obtaining the desired channel. These results are confirmed based on the simulation study executed in a laboratory environment. Further, these results from the simulation encourage future research in the areas of parallel batch scheduling.

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