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RESEARCH ARTICLE

A Hybrid Burst Assembly Algorithm Based on Transition Count Number for OBS Network

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Abstract

Background: Optical transport has emerged as a candidate solution to cope with the rising data transmission challenges of enormously evolving data. In Optical Burst Switching (OBS) networks, determining an adaptive burst size is a difficult task that must be performed efficiently during burst assembling. **Methods:** This research proposes a hybrid burst assembly algorithm that determines the optimal burst size during the burst creation time. The proposed algorithm uses the Transition Count Number (TCN) based method to maintain the optimal burst size when the incoming traffic is unpredictable. The efficiency of the proposed approach is investigated in terms of queuing delay, burst utilization, burst size, and burst size consistency. **Findings:** Three types of traffic variations (H = 0.5, H = 0.6, and H = 0.7) are imposed to evaluate the performance of the proposed burst assembly approach. As compared to the E-hybrid (time/length) strategy, the research outcomes demonstrate a 13.15% reduction in average queuing latency and a 21.26% improvement in average burst utilization. **Novelty:** A new burst assembly approach (hybrid burst assembly) has been proposed for OBS networks.

Keywords: Burst assembly; Optical Burst Switching (OBS); burstification; burst consistency

1 Introduction

The development of new technologies (cloud computing, IoT, 5G etc.) increases bandwidth requirements every day. According to the Economics Times research [1], Asia has had the network's largest growth between 2019 and 2021. During the pandemic, the ordinary global internet traffic grew from 120 Tbps to 170 Tbps [2]. The network traffic during COVID-19 has increased by about 40% compared to what was anticipated to be 28% from 2019 to 2021 [3,4]. The most effective alternative and innovation in computer networks to address the bandwidth problem is optical burst switching. [5]. Three switching approaches, such as Optical Circuit Switching (OCS), Optical Packet Switching (OPS), and Optical Burst Switching (OBS), are available for optical communication. Optical burst switching (OBS) aims to combine electronics and optics in the best possible way to dynamically provision sub-wavelength granularity. OBS has a finer granularity than OCS and OPS as a result as shown in Table 1. The burst assembly is a most challenging task of the OBS network which is performed at the ingress node. The collection of packets with similar properties is called a burst[6,7].

Table 1. Capability comparison of OCS, OPS, and OBS techniques

Approach	OCS	OPS	OBS
Granularity	Coarse	Fine	Moderate
Bandwidth Utilization	Low	High	High
Setup Latency	High	Low	Low
Switching Speed	Slow	Fast	Moderate
Processing Complexity	Low	High	Medium
Traffic Adaptively	Low	High	High

Two main objectives of any burst assembly technique are to increase the burst size and minimize the packet delay in the assembling queue, which decreases the overall end to end delay. But there is a trade-off between burst size and queuing delay, as shown in Figure 1 when rise in data burst-length (BL) and corresponding increases in burst queuing delay (QD).

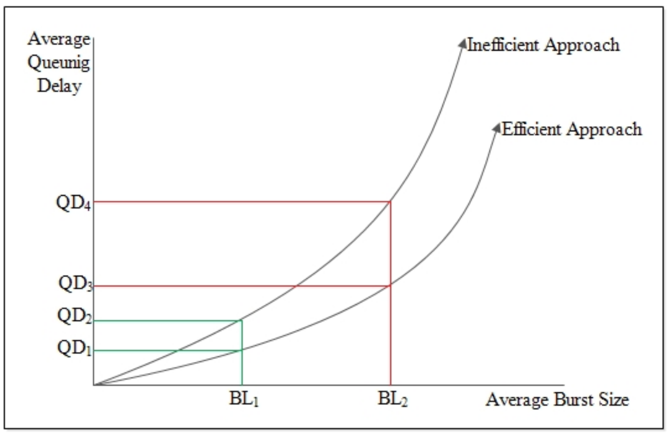

Fig 1. Performance of "efficient "and "inefficiency" burst assembly approaches

Time-based burst assembly and length-based burst assembly are the two fundamental methods for the burst assembly process in OBS networks. When a predefined time limit is reached in time-based burst assembly, all packets that would have arrived within that duration are combined into a burst. It is important to determine the time-period value carefully, as excessive values may generate irrational queuing delay during the burst assembly process. The other issue is that several little bursts would be produced if the value is low, which would result in a huge control burden at the core nodes[8–10].

In burst-length based approach, the creation of a burst is determined by a predetermined burst length**.** A burst is produced and sent to the proper output port after it reaches the specified burst length. The disadvantage of this approach is that it can take a while to reach a specified length because of the volume of incoming traffic, which would result in unfavourable delays at the input node. When traffic is fast, a lower threshold of a specified length will cause several bursts to be generated, imposing a significant control burden on the core nodes[11,12].

The shortcomings of time-based and length-based techniques is avoided through a Time-Length-first approach. This method assembles a burst upon reaching either predefined Length or Time, whichever occurs sooner[13]. Extended-Timer-Based assembly algorithm and Fixed-Time-Min-Length assembly algorithm are the efficient versions of Time/Length hybrid approach[14,15]. There are some approaches in the literature which uses the incoming traffic rate as a parameter to set the size-burst[16,17].

In this paper, a hybrid burst assembly algorithm is proposed which uses the TCN-based approach to maintain the optimal burst-size for unpredictable incoming traffic. Using TCN, the burst size is determined in a discrete and dynamic mode. TCN is a discrete burst size representation that has T_{upper} and T_{low} limits for a stage of burst size. A Run-Time-Burst algorithm is used to adjust the burst-size in order to minimize the queuing delay and retain the standard burst-size. The proposed approach is compared with the traditional approaches in terms of queuing latency, burst utilization, burst size, and burst size consistency.

2 Methodology

The paper presents the implementation of a hybrid burst assembly approach (Run-Time-Burst) in an OBS environment. Channels-1 (C1) and Channel-2,3 (C2 and C3), respectively, describe the functionality of edge and core nodes. The proposed assembly algorithm is contained in C1 (ingress node). This section is broken up into two modules: the first module contains the OBS network implementation, while the second module contains the burst assembly algorithm (Run-Time-Burst).

2.1 Implementation of OBS Scenario

The ingress node of OBS network provides the interface with other networks which receives the IP based traffic. Optical link and node are the basic components of OBS network. A classifier module is established at the entrance which classifies the optical burst and IP packets. Optical routing provides the support for this implementation [12,18]. The functionality of ingress, core and egress nodes are combined in a single module which is indicated by C1, (C2) and (C3) as shown in the Figure 2.

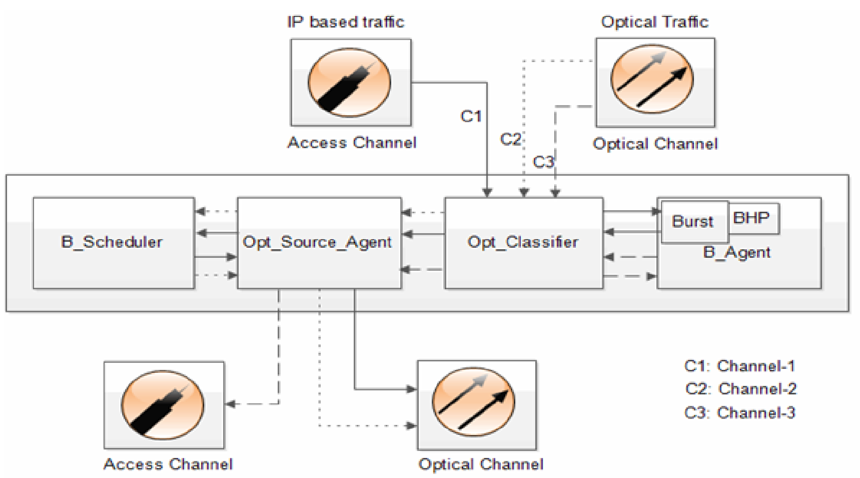

Fig 2. Implemented modules of OBS network

Channel-1 indicates the process of burst assembly which begins when IP traffic arrived at the optical domain from the electrical domain. Opt_Classifier sends the IP-traffic to the burst agent (B_Agent) after determining that the upcoming node for this traffic is in the optical domain. The IP-traffic is placed in a burstification queue by B_Agent in line with a burst header packet (BHP) and burst pair. The related BHP of a burst that is set to be transmitted is sent to Opt_Classifier and then routed to the Opt_Source_Agent, which is an optical source routing agent [19]. The Opt_Source_Agent sets the payload in the burst with corresponding control information in the BHP. It then uses the B_Scheduler block to seek for the right period. This block contains the Opt_Schedule, Opt_FDL_Schedule and Opt_Converter_Schedule, which typically maintain track of reservations for wavelength converters, and output channels, respectively. Opt_Source_Agent transmits the BHP and prepares the burst to be sent after an offset duration if a sufficient time-period and resources has been identified. If not, the burst is discarded [20,21]. Minimum Starting Void (Min-SV) [22] and Latest Available Unused Channel with Void Filling (LAUC-VF) [23] are the scheduling algorithms that are being used by B_Scheduler block. To route bursts within the OBS network, OBS uses the minimum-hop path between the ingress and egress nodes.

Opt_Source_Agent basically improves the handling process to optical traffic. All the nodes (optical and electrical) and routes information is contained in the Opt_Source_Agent module. As a result, clients can choose the traffic paths based on the routes created by the selected routing programs. All the nodes send recently created packets to Opt_Source_Agent, which records the route that the packet will travel in the BHP [24]. To put it simply, the burst assembling process begins with the Opt_Source_Agent, where routing information for the traffic is recorded, and continues to the Opt_Classifier, which will then transmit the traffic to the B_Agent [25].

In order to simplify the model and make it easier to modify or add methods, the necessary functionalities of optical nodes have been organised into four distinct modules (B_Scheduler, Opt_Source_Agent, Opt_Classifier, and B_Agent). The identical features of B_ Scheduler, Opt_Source_Agent, and Opt_Classifier are required by all optical ingress, egress, and core nodes. The main distinction between these two sorts of nodes is that core nodes might not require a B_Agent if the core node never goes through burst assembling and re-assembling process. On the optical core nodes, certain clients would also have to install traffic agents and assembling/re-assembling. There is not any requirement to identify the kind of the optical node when implementing it because ingress, egress, and core nodes all use the identical node design [23].

Channel-2 (C2) specifies the optical transmission, all the optical traffic has been received by the Opt_Classifier from optical domain as shown in Figure 1. Opt_Classifier sends the traffic to the Opt_Source_Agent, which asks the B_Scheduler module for an adequate reservation because the subsequent node is in the optical domain. The BHP is transmitted to the related WDM channel if the optical packet is a control packet and the reserve the resources for the corresponding burst if feasible [18]. The burst is transmitted to the WDM channel if the BHP is a burst and a reservation has already been established. The optical packet gets discarded if not. Opt_Classifier transmits the optical traffic to the B_Agent for de-assembling when the destination node is not in the optical domain (C3). The optical traffic is discarded if it contains a BHP. If it is a burst, the Opt_Classifier sends the packets contained in the burst to the Opt_Source_Agent. This traffic is sent by Opt_Source_Agent across outgoing electrical domain to the desired nodes [7].

2.2 Proposed Burst Assembly Algorithm

The main motive of this algorithm is to minimize the waiting time of packets in the assembling queue. Transition Count Number (TCN) is used to compute the burst size in a discrete and dynamic manner. TCN is a representation of the distinct burst size stages.

Algorithm: Run-Time-Burst is an algorithm to decides the size of burst dynamically and continuously. The size of TCN and numbers of steps between BS_{low} and BS_{high} are predefined to avoid the control overhead on network. The size of each burst must remain between BS_{low} and BS_{high} .

Set of identifiers which are used in the algorithm as:

BS: Burst size

TCN: Transition Count Number

T_{max}: Maximum period of time for burst to waiting in queue

B_{size}: Currant size of burst

UB (Upper Bond): Maximum burst size in current TCN

LB (Lower Bond): Minimum burst size in current TCN

BS_{high}: Largest possible burst size

BS_{low}: Smallest possible burst size

T_{low}: Minimum time limit

T_{upper}: Maximum time limit

Q_{size}: Current queue size

Run-Time-Burst Algorithm:

1. Receive the packets in the assembly queue of the ingress node and initialize the T_{max}

2. Set TCN = 0 AND B_{size} = BS [Initialize the burst size according to the incoming traffic flow]

3. IF (TIMER < = T_{max}) THEN

3.1 IF ($Q_{size} > T_{low}$ AND $Q_{size} < T_{upper}$) THEN

3.2 CREATE BURST AS Q_{size} [Create burst with the current queue size]

3.3 ELSE (Else of 3.1)

3.4 IF ($Q_{size} < T_{low}$) THEN

3.5 IF ($Q_{size} > T_{upper}$) THEN

3.6 RETAIN SAME BURST SIZE [Don't change the size of Q_{size}]

3.7 ELSE (Else of 3.5)

3.8 TCN = TCN + 1 [Increase the TCN by one step]

3.9 IF (TCN > UB) THEN

3.10 IF ($B_{size} = BS_{high}$) THEN

3.11 INCREASE B_{size}, T_{low} and T_{upper} AND RESET TIMER [Increase the burst size]

3.12 ELSE (Else of 3.9)

3.13 RETAIN SAME BURST SIZE [Don't change the size of Q_{size}]

3.14 ELSE (Else of 3.10)

3.15 RETAIN SAME BURST SIZE [Don't change the size of Q_{size}]

3.16 ELSE (Else of 3.4)

3.17 TCN = TCN – 1

3.18 IF (TCN < LB) THEN

3.19 IF (B_{size} > BS_{low}) THEN
3.20 DECREASE B_{size}, T_{low} and T_{upper} AND RESET TIMER [Decrease the burst size]
3.21 ELSE (Else of 3.19)
3.22 RETAIN SAME BURST SIZE [Don't change the size of Q_{size}]
3.23 ELSE (Else of 3.18)
3.24 RETAIN SAME BURST SIZE [Don't change the size of Q_{size}]
3.25 ELSE (Else of 3)
3.26 RESET T_{max} AND REPEAT STEP 3.
4. STOP

The proposed algorithm reduces burst size fluctuation, which decreases control overhead at the core nodes and queuing latency at the ingress node in the OBS network. The proposed approach performs exceptionally well as compared to earlier approaches when the incoming traffic load is unexpected. Step-wise explanation of the proposed algorithm is given follow:

a. To set the value for T_{max}, which is completely depends on the current incoming traffic flow and variation.

b. A timer begins when a packet is received and reaches its destination position in the assembling queue. Q_{size} will be examined if the timer value is less than or equal to the T_{max} value. However, a new burst will form if the Q_{size} is smaller than T_{upper} and greater than T_{low}; otherwise, the burst's size will alter.

c. T_{low} and T_{upper} determine TCN's value. If T_{upper} is less than or equal to TCN, TCN will be reduced by one; otherwise, TCN will be increased by one.

d. In the situation that TCN is less than LB, queue and burst sizes are correspondingly reduced. In the case that queue and burst size are not altered, the values of LB and UB will likewise be lowered to a smaller TCN (TCN-1). The queue and burst sizes remain the same. If the value of TCN is higher than UB. In this case, the queue and burst sizes are increased by one, and the LB and UB are increased to greater TCN (TCN+1). Repeat steps (c) through (e) to modify the size based on the rate of incoming traffic.

e. Reset the timer and go to step (c)

The total quantity of packets (m) received during the assembly time and if the completed burst is shorter than BS_{low} are the primary factors determining the complexity of the proposed algorithm for one TCN stage. The proposed algorithm's complexity is O(m) if the completed burst is not shorter than BS_{low}. There is no need to change the stage of the current TCN in this scenario. The complexity of the proposed approach is $O(m \times n)$, where n is the number of assembly queues, and it needs to upstage the current TCN if the resultant burst is less than BS_{low}.

3 Results and Discussion

The section is dedicated for the performance analysis of the proposed Run-Time-Burst algorithm. The parameter used for the deployment of the OBS network are described in Table 2.

Table 2. Simulation Parameters

Parameters	Description
Area	1200 m^2 with a transmission radius of 1200m
Transmission Range	200m
Number of end users	10 source nodes and 10 destination nodes (total = 20)
Number of Edge nodes	2
Size of packets	2 kB
Average link capacity	200 Mbps
Propagation delay	1.2 ms
Default values of BS_{high} and BS_{low}	BS_{high}: 180 kB and BS_{low}: 64 kB
Simulation Rounds	10000
Simulator	NS2 (nOBS) and Matlab version 2016a
Evaluation Parameters	Burst size consistency, Burst utilization, Queueing delay (Burstification), and burst size variation

Figure 3 depicts a 21 node topology for simulation where a WDM link is connecting node-0 and node-1. The obtained observations are analysed using the Matlab version 2016a tool on an area of 1200 m^2 with a transmission radius of 1200m, along with the established simulated environment configured on a server with 8GB of RAM memory and an i5 processor.

Using three traffic variations, the efficiency of the assembling method is evaluated in terms of burst utilisation, burstification time, and burst size consistency. To study the impact of varying traffic load and other features, IPv4-based traffic is generated with an average packet length of 2 KB and burstiness ranging from H=0.5 to H=0.7 for moderate traffic. The computational investigation of the burst assembling structure and characteristics on the performance of traffic flows is described in this work. In this simulation, simple Bernoulli dispersed drop rate denoted as Dp, 2 Gbps capacity, and 12 ms propagation time are used to describe the core node structure. Each access link transmits three different types of traffic to the source node, but overall, all links have an average capacity of 200 Mbps and a propagation delay of 1.2 ms. With a hybrid size/timer-based burst assembling techniques, the overall efficiency for M=20 traffic flows with Dp=0.01 and M=20 is evaluated over a variety of assembling time thresholds and burst-size thresholds.

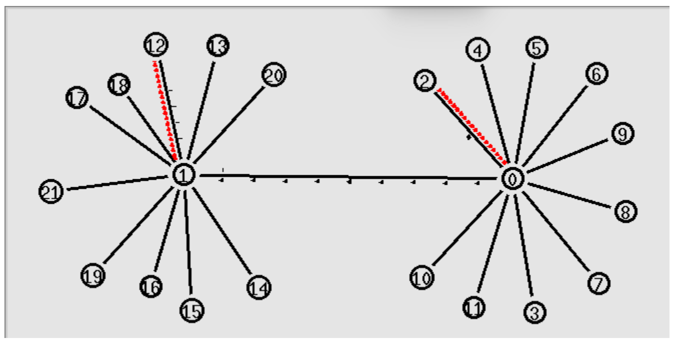

Fig 3. Simulation of proposed architecture

To prevent the restriction on the growth of the congestion window, all the receive windows of receiving node are assumed to 20,000 MSS. We employed the OBS functionality that permits ACK traffic to not be buffered in order to figure out how the queuing delay affects the performances. To assess the efficacy of the assembling techniques in terms of packet queuing time, burst utilisation, and burst size consistency, a traffic model with moderate traffic variation properties has been developed. Traffic that is sporadic throughout some or all period ranges can be statistically described using the idea of self-similarity. A measure of a time series' degree of self-similarity is the Hurst parameter H. H takes amounts between 0.5 and 1. Figure 4 shows the imposed traffic with H value to evaluate the performance of network. The performance of OBS model has been evaluated according to Time based threshold (Time) [26], Length based threshold (Packet) [15], Time/Length based threshold (E-Hybrid) [27] and traffic prediction based (Hybrid) [17] burst assembly as shown in Figures 5, 6, 7 and 8.

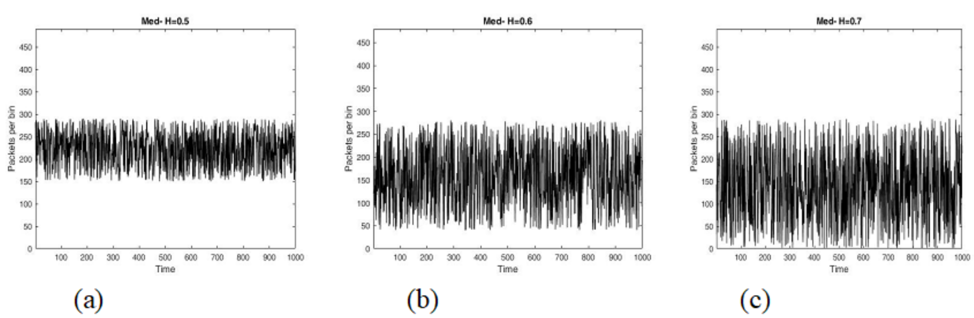

Fig 4. Three traffic variation with (a) H = 0.5, (b) H = 0.6 and (c) H = 0.7

Every burst assembly strategy has two main objectives: the first is to reduce the packet delay during queue assembly in order to reduce the overall delay, and the second is to increase burst size. Large burst sizes do, however, result in fewer bursts produced, which minimises the processing load on the core nodes. As a result, when a packet enters the system from a source node, it is placed into a burstification queue based on its destination or priority. The size of the data bursts is determined by the rate of incoming traffic and is produced using the burst assembly approach. Figure 5 shows the burst size created by different assembly approaches when the traffic load (as shown in Figure 4) is supplied. The performance of time-based approach is very low as

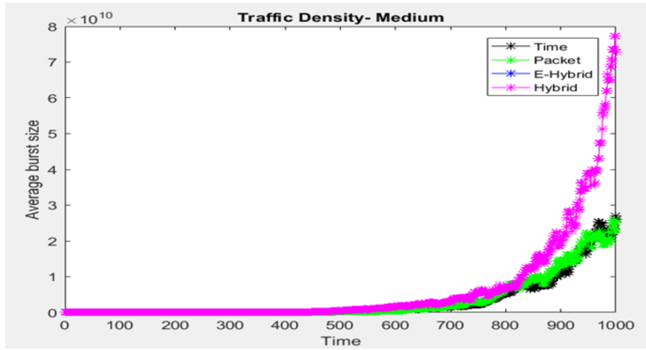

Fig 5. Burst size variation by different burst assembly approaches

compare to other approaches in terms of burst size.

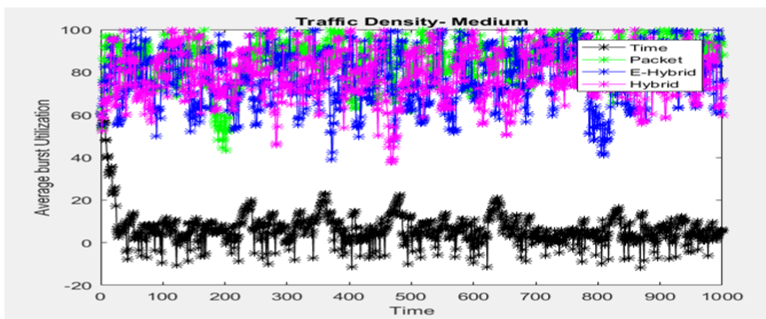

Fig 6. Burst utilization by different burst assembly approaches

In exponentially distributed traffic, Figure 6 compares the average data burst utilisation for different burst assembly approaches. The ratio of the total IP packet size in the data burst to the data burst size is known as the data burst utilisation. When the supplied load is less than H-0.5 using the hybrid approach, the variable burst provided higher data burst utilisation. The hybrid approach decreases the likelihood of continuous blocking in the bandwidth reservation request by offering a shorter timer operation. The padding bits have been used to complete the burst size by proposed approach.

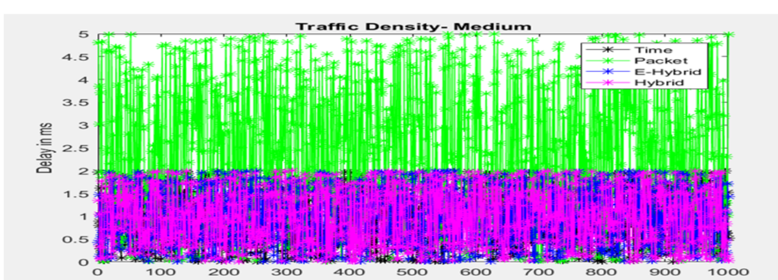

Fig 7. Burstification of packets by different burst assembly approaches

The average delay for several traffic models with different assembly approaches is compared in Figure 7. As anticipated, the hybrid data burst assembly technique maintains a low average delay using discrete TCN steps. The dynamic behaviour of hybrid approach keeps a low average packet delay time during burst production as compared to other approaches. The length-based assembly approach is performed very poor.

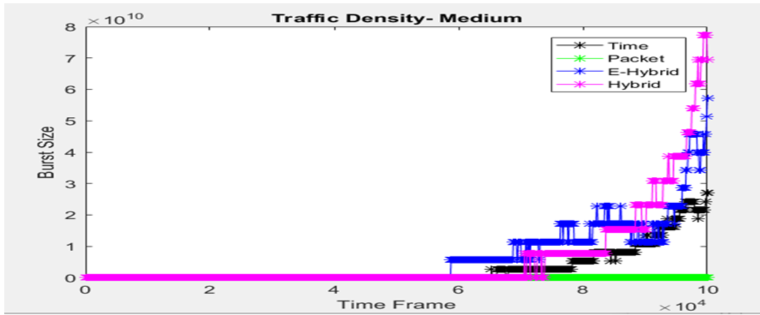

Fig 8. Burst size consistency with respect to time frames

The discrete type burst size decision mechanism is implemented to observe the burst size consistency. In terms of the transition count number, a burst size has a number of stable states. The burst size is raised one step if the transition count reaches the upper bound. The burst size is decreased by one step if the transition count falls below the lower bound. Figure 8 depicts the way the data burst size changes in supplied traffic load. Compared to other approaches, the hybrid approach can sustain the same burst-size over an extended period of time.

However, ns2 lacks many of the components for simulating optical burst switching networks. More detailed investigations of OBS network can be done by implementing various features (contention resolution, BHP processing, wavelength assignment, Signalling and disassembly) of the core and egress nodes in ns2.

4 Conclusion

Based on the dynamic burst size selection, we proposed a new burst assembly approach (hybrid burst assembly) for OBS networks in this manuscript. In the proposed approach, the discrete type burst size decision mechanism is implemented to observe the burst size consistency and Transition Count Number (TCN) is used to compute the burst size in a discrete and dynamic manner. The non-linear properties are implied by this algorithm to reduce the burst-blocking problems at the ingress node. This algorithm's primary goal is to reduce the amount of time packets in the assembly queue must wait. Additionally, this approach makes sure that the sent burst-size is neither too long nor too short, which might affect the OBS network's performance. The efficiency of proposed algorithm has been evaluated by comparing with traditional assembly approaches (Time based burst assembly, Length based burst assembly and Time/Length based burst assembly) in terms of queuing delay, burst utilization and constant burst size. As compared to the E-hybrid (time/length) strategy, the research outcomes demonstrate a 13.15% reduction in average queuing latency and a 21.26% improvement in average burst utilization. The results may be improved in future by combining the traffic-rate prediction based and dynamic burst assembly schemes.

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