THE ADAPTIVE CONTENTION RESOLUTION MECHANISM FOR OPTICAL BURST SWITCHED NETWORK

Dilip Patel [1], Dr. Kiritkumar Bhatt [2], Dr. Jaymin Bhalani [3]
[1] Electronics & Communication Dept, LDRP Institute of Technology and Research, Gandhinagar, India
[2] Professors, Electronics and Communication Department, Sardar Vallabhbhai Patel Institute of Technology, Gujarat, India
[3] Professor & HOD, Electronics and Communication Department, Babariya Institute of Technology, Baroda, Gujarat, India.
Email:[1]dilip_ec@ldrp.ac.in

Abstract — In Optical Burst Switched (OBS) Networks, data is transported in buffer less network and hence there is fair amount of chances of contention among the bursts. Many Burst retransmission schemes have been proposed in the literature to deal with bus contention. Burst retransmission gives better throughput performance for higher layers. The random retransmission mechanism often leads to unprecedented increase in network load. In many cases, retransmission of lost burst beyond allocated time offers no benefits. Also the existing retransmission schemes do not provide an accurate relationship between impact of network load due to retransmissions and improvement in the successful burst transmission rate. In this paper we propose an Adaptive Burst Retransmission Mechanism (ABRM) incorporating parameters to control the rate of retransmission and thereby effectively manage the increase in the network load. An analysis of the model evolved is also presented. A metrics is evolved to evaluate merits of retransmission and its impact on the network performance with proposed retransmission parameters. The analytical and simulated results of DBRM scheme is compared with no retransmission scheme. The results show that the proposed mechanism provides adaptive burst retransmission wherein, the parameters can be changed dynamically to fulfill the criteria of end-to-end burst loss rate and path blocking.

Index Terms—Burst retransmission; Burst loss probability (BLP);
Path blocking probability; Optical burst switching

I. INTRODUCTION

In the networking scenario, the Optical Burst Switched (OBS) network is consider as most mature all-optical architecture [1]. The burst is created for transmission of user data and it is pass through entire optical route in optical domain without undergoing optical to electrical conversion. For each generated burst, the control burst packet is transmitted in advance and it undergoes the electrical conversion process at each intermediate node along the route from source to destination. The separation of data plan and control plan leads to flexibility and scalability of OBS network. The dynamic nature of OBS network is more appropriate for handling bursty internet traffic [2]. Due to bufferless and connectionless nature of OBS network, the burst may face contention at intermediate nodes. The contention is generated if more than one burst arrives at a time on single node and asking for the same output link or port.

The fiber delay lines (FDLs) is used for buffering the signal and thus reducing the contention. In FDL, the light is stored through delaying the optical signal by using very long fiber [3]. Another contention resolution scheme is wavelength conversion, wherein wavelength of input port can be converted to different wavelength at the output port. Network with few wavelengths, the available wavelengths can be again used for transmission of signal with different output using wavelength conversion [4]. With burst segmentation scheme [5], during contention the overlapping burst portion is divided into smaller segments and it is again transmitted. It results into lower burst loss ratio. Another scheme known as deflection routing used for contention resolution. Wherein, the data burst is transmitted to another route than the original route in contention scenario. It results into poor network performance [6] as it creates long looping of data bursts. The performance comparison of these schemes has clearly shows that all these above proposed scheme has its own technical and economical limitations [7, 8]. For contention resolution, these schemes only give partial temporary solution as they cannot entirely remove the endto-end burst loss due to contention. Therefore, the dynamic burst retransmission mechanism (DBRM) for contention resolution. Also, it provides a mechanism for evaluation of increase in network traffic and controlling the retransmission rate. The rest of the paper is organized as follows. Section II covers a comparative brief about the related work. Section III describes the proposed retransmission mechanism with new retransmission variables and modified ingress node structure. An analytical model with wavelength conversion for evaluating the network performance is presented in Section IV. The proposed model is validated with simulations and the performance of the network under burst retransmission is investigated in details in the Section V. Finally, section VI concludes the paper.

II. RELATED WORK

For reducing the end to end burst loss, the retransmission mechanism [9] has been proposed. The performance studies of retransmission scheme reveal that burst loss probability (BLP) improved as lost TCP packets are retransmitted from its source [9, 10]. The partial burst retransmission scheme with burst segmentation have been presented in[11] and its results shows improvement in BLP as only discarded segments packets are retransmitted. A hybrid scheme combing the deflection routing and burst retransmission [12] gives better performance compared to simple retransmission or deflection method for BLP and rate of burst transmission. Even through, burst retransmission gives better BLP performance but it also generates extra load in the OBS network. In OBS network contention is natural fact, just static retransmission without any discrimination leads to a radical increase in the network traffic, BLP and thus the sidetrack the very goal of burst retransmission. The existing retransmission approaches [10, 13] fail to provide relationship between the improved end-to-end BLP and extra load generated with retransmission attempts. They do not provide any upper bound to generated load due to retransmission and it result into poor delivery rate and drastically increase the storage capacity at ingress node. Also, they cannot control the burst retransmission rate and thus constant increases in generated traffic load. Also, these schemes [10, 13] maintain the assumption that the load on each link along the path is equal which is not untrue in reality.

A novel mechanism for burst retransmission in a dynamics fashion is presented in this paper. This approach effectively handles rapid increases in the network traffic. It considers new retransmission parameters that provide upper bound on traffic due to retransmission. These parameters dynamically control the number of burst need to be retransmitted and again retransmitted when the burst is lost during transmission attempts. The accurate analysis presented here shows definite relationship between extra load generated due to dynamic retransmission and improvement in the BLP. We provides a model for calculating the exact value of arrival traffic due to transmitted bursts, retransmitted bursts and value of the number of retransmission attempt along a path in core network. A metrics is evolved to check the benefits of retransmission and its impact on the network performance.

III. PROPOSED DYNAMIC BURST RETRANSMISSION SCHEME

At the OBS layer, it is critical to carefully study the effect of burst retransmissions on the generated extra network load and burst loss. In many practical applications, the burst retransmission may not be always required for successfully sending the lost burst to its destination like ARQ method. TCP based transmission many retransmission attempts would be useless if the timer expire. Furthermore, some application needed certain loss rate and thus the retransmission of bursts can be determined to fulfill the loss rate criteria. Therefore, it is not required to retransmit all the lost burst. Focusing on this different traffic scenario, we propose dynamic burst retransmission approach which can effectively control the rate of burst retransmission.

We consider a D_1 known as onetime probability for achieving partial burst retransmission and it represent the probability of lost burst that can be retransmission for onetime only. When D_1 is equal to one it means it retransmits all the lost bursts. In general, the D_1 can be set to partial value for satisfying different traffic conditions and quality of service requirements wherein the some of the lost bursts need to be retransmitted. We consider a D_2 known as the many time probability and it represent the probability for lost of onetime retransmitted burst and again need to retransmit with many attempts. The value of D_2 can be figure out as per need traffic condition. Besides retransmission variable D_1 and D_2 which enable partial retransmission of lost bursts, we introduce parameter *N* known as number of retransmission attempts for controlling an upper limit of traffic entering to core OBS network. The proposed work presents a smooth mechanism which can adopt the different value of retransmission rate and measure performance based on it.

The redefined ingress node has two addition block, the copy of burst (COB) block and the burst scheduler (BS) block. The COB block is used for maintaining the copy of transmitted burst and BS block is used to retransmit the lost bursts with appropriate time and to access acknowledgements from the destination node. Once the burst is transmitted and it is lost because of contention then we need to retransmit the burst with probability of D_1 from COB. Therefore, the probability of initially transmitted burst does not undergoes retransmission is $1 - D_1$. Again, if the retransmitted burst lost due to contention then we need to retransmit it from COB with probability of D_2 for multiple retransmission attempts. Therefore, the probability of burst that is lost during retransmission and does not undergo further retransmission process is $1 - D_2$. When retransmission is not desirable for the lost burst then the copy of burst is eradicated from the COB block. We assume loss free control channel for smoothly managing the acknowledgement messages. Also, the BS maintain acknowledgement up to one cycle of round trip time for all the bursts and then it simply discard the burst from COB. The burst generated by various assemblers are assigned unique number for each source and the destination pair. When a burst is generated from assembly unit, it is sent to all the main scheduler, BS and the COB. At the burst assembly unit, the main scheduler informs the BS about plan for first time transmission of burst and thus BS carefully observed for the acknowledgement messages of burst retransmission.

IV. MATHEMATICAL ANALYSIS OF THE PROPOSED SCHEME

The λs is the arrival rate of bursts on the path S and the ηs is the departure rate of retransmitted bursts from the COB and both are assume to be poisson process. The shortest path is used for all the burst between an ingress and egress node. Total number of all possible shortest paths in the network is T considering all ingress-egress node pairs and the number of all shortest path crossing the core node C is given by R(c). The blocking probability of a path S is Rs and it can be calculated by,

$$R_s = 1 - \prod_{C \in S} (1 - N_C) \qquad (1)$$

The blocking probability of the node c is Nc . At the SBC considering steady state balance, the number of bursts inline for retransmission is same as number of burst are already retransmitted [9] and an equation for SBC can be written as,

$$(D_1 \lambda_S + D_2\, \eta_S) R_s = \eta_S \qquad (2)$$

The actual arrival rate is addition of arrival rate due to initially transmitted burst and arrival rate due to one and or multiple time retransmitted burst. The actual arrival rate $\lambda_{-S}$of bursts is written by

$$\bar{\lambda}_S = \lambda_S \left(1 + \frac{R_S D_1}{1 - R_s D_2}\right) \qquad (3)$$

In order to reduce the extra load generated due to retransmission we limit the number of retransmission attempts to J and the actual arrival rate can be calculated by

$$\bar{\lambda}_S = \begin{cases} \lambda_S & \text{if } J = 0 \\ \lambda_{S\left(1+R_S D_1 \left(1-(R_S D_1)^J \middle| 1-R_S D_1\right)\right)} & \text{if } J > 1 \end{cases} \qquad (4)$$

In relation to these equations, both for transmitted and retransmitted bursts we assume the equal value of Rs with almost equal timing between the arrivals of both burst. At a particular node in network, the actual load can computed with the value of node blocking probability of path and the arrival traffic from the number of path crossing to that node. If the node have wavelength converter then the value of node blocking probability differ from that of node without converter. Below, we present analysis of a node with iterative equation of actual load and actual arrival rate in relations to burst retransmission.

(A) WITHOUT WAVELENGTH CONVERSION

The λs,c represent the actual arrival rate of bursts on node C with load on the path S. The μc is service rate at node C

and it is exponentially distributed. It can be calculated by

$$\rho_C = \mu_C^{-1} \sum_{C \in T(C)} \lambda_{S,C} \qquad (6)$$

In a very small time period Δr, the probability of a burst serviced by the node C is μcΔr. It can easily be computed using the Erlang's loss formula with M/M/1/1[10] server by

$$N_C = \frac{\overset{\rho}{c}}{1 + \rho_C} \qquad (7)$$

By comparing the actual departure rate of node C and

actual arrival rate of node H for a link (C, H), we can write,

$$\lambda_{S,H} \nabla t = (\mu_C \nabla t)(\rho_C | 1 + \rho_C) \left(\lambda_{S,C} \middle| \sum_{S \in T(C)} \lambda_{S,C} \right) \qquad (8)$$

We can derived the actual arrival rate at node H with traffic on path S by putting the value of λs,c from equation (6) into equation (8). In other words, the last part of above equation on right side represents the service probability of node C. Thus, we can write,

$$\lambda_{S,H} = \frac{\lambda_{S,C}}{1 + \rho_C} \qquad (9)$$

Under steady state, λS, H is almost same as actual arrival rate λS of burst considering all ingress nodes along the path S. We can be clearly observed from equation (6) and equation (9) that the actual arrival rate can be calculated in an iterative fashion at the core node. Based on knowledge of actual load and actual arrival rate of previous hop, we can easily calculate the actual load on a node for given path. By repeating the same process, we can know the actual load on all possible incoming paths from source node.

(B) WITH WAVELENGTH CONVERSION

The similar analysis can be carried out for a node with wavelength conversion by adding change in the blocking probability. A node with full wavelength conversion ability

with B wavelengths, the blocking probability can be calculated by Erlang B equation [10],

$$\rho_C = E(\rho_C, B) = \frac{\frac{\rho_C^B}{B!}}{\sum_{a=0}^{B} \frac{\rho_C^a}{a!}} .. (10)$$

By comparing actual departure rate of bursts from node C and the actual arrival rate of immediate node H, we can write,

$$\lambda_{S,H} = \lambda_{S,C} \left(1 - \frac{\rho_C^B}{\sum_{a=0}^{B} \frac{\rho_C^a}{a!}}\right) \ldots (11)$$

After calculating the exact arrival rate and exact load under steady-state, we are presenting performance metrics to measure the actual gain in the end to end BLP with increase in extra load due to burst retransmission.

(C) METRICS FOR PERFORMANCE MEASUREMENT

We define burst success probability (BSP) as the increased ratio of bursts successfully received at destination due to dynamic retransmission. The D_S is BSP with retransmission and (1 − Ds) is the BSP without retransmission on a path S.

Thus, the improved BSP on a path S can be calculated by,

$$\Delta_S = P_S - (1 - D_S) \qquad (12)$$

Equation (12) reveals that the retransmission is effective with positive value of Δs only. By adding the improved BSP of all possible paths, the total improved BSP of whole network is calculated by,

$$\Psi = \frac{\sum_{S\in T} \bar{\lambda}_S \Delta_S}{\sum_{S\in T} \bar{\lambda}_S} \qquad (13)$$

The end-to-end throughput for network can be calculated by adding the actual arrival rate of total number of burst successfully sent on all possible paths in network by,

$$\eta = \sum_{S\in T} \bar{\lambda}_S (1 - \bar{D}_S) \qquad (14)$$

V. RESULT ANALYSIS and DISCUSSION

The vBSN topology is consider for the core OBS network with three source nodes and three destination nodes connected Fig. 2. We have developed C++ code for simulation work and it contains all the required OBS functional modules. We are using 32 wavelengths for each link and extra 4 control wavelengths. The 10 Gbps of transmission rate selected on each wavelength. In our work, the MTTAS algorithm, JET protocol and LAUC-VF scheduling algorithm is used [14]. The packets are generated randomly between the all pair of ingress-egress node with random start times. We have calculated the normalized load by averaging the actual load with whole network and its values is from 0.4 to 0.9. The network performance was carried out for main two parameters, the throughput and gain in BSP (Ψ). We compare the results of proposed work with no retransmission scheme [7].

For without wavelength conversion, the Fig.3 shows the result of path blocking probability (PBP) against load. The higher values of D_1 and D_2 results in rapid increase in PBP and it further increases with increase in network load. For without wavelength conversion, the Fig.4 shows the result of BLP against load. The observation reveals that with higher D1 and D2 values we get very small BLP. Regardless of retransmission values, the BLP increase with the higher value of load but intensity of rapid increase in BLP become steady with higher values of D_1 and D_2. Next, the effect of dynamic retransmission on network performance is considered. We observed the improved BSP (Ψ) by increasing J and then we fix the optimal value of J for simulation work. Also, the effect of D_1 and D_2 measured on BLP and path blocking.

(A) THE EFFECT OF J

As the number of retransmission attempts *J* increases the extra load in the generated in network and it result into higher BLP with missing the very purpose of burst retransmission. We limit the optimum value of *J* in such way that it offer the best BLP and improved BSP. The Fig.5 llustrate the variation in BLP and improved BSP ( ) with respect *J* for whole network. The results reveal that when *J* is beyond five the performance improvement in and in BLP is nil. Therefore, we limit *J* equal to 5 as optimum value.

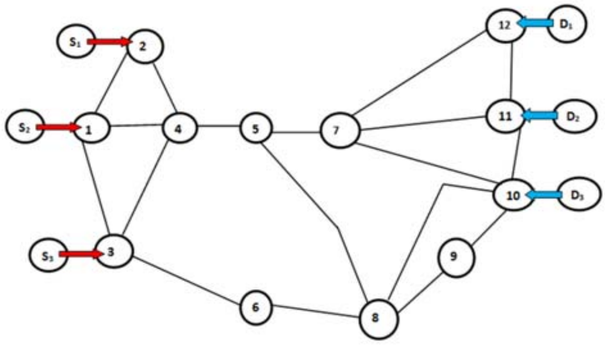

Fig - 2 The core OBS vBSN topology with connected three source nodes (S1, S2, S3) and three destination nodes (D_1, D2, D3).

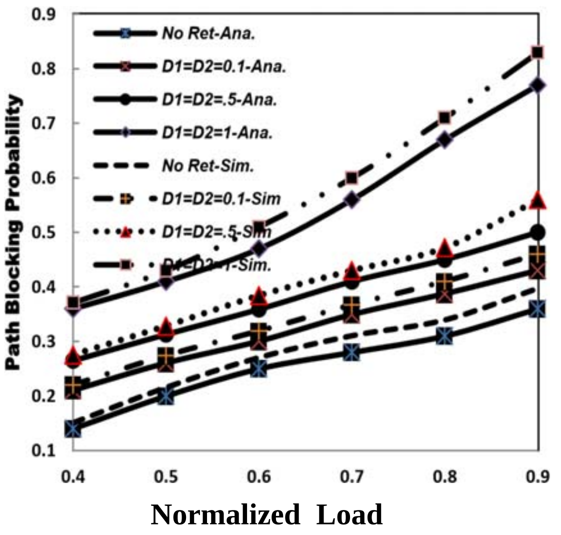

Fig- 3 Path blocking probability against normalized load without wavelength conversion facility.

(B) THE EFFECT OF D_1 AND D_2

The Fig.6 illustrate the effect of the D_1 and D_2 (retransmission variables) on the average BLP and path blocking probability in the network at normalized load 0.6. Wherein, we keep D_2 kept equal to 1 and variation in the D_1 is observed. In fig. 6 for with wavelength conversion scenario, the upper portion of graph indicates path blocking and the lower portion of graph indicates BLP of whole network. With increases in D_1 the BLP is gradually reduces and path blocking increases as depicted in Fig.5. Similar graph is obtained (graph is excluded due to lack of space) wherein D_1 is kept to unity and D_2 various is observed for load at 0.6. With increases in D_2, the reduction in BLP and rapid increases in path blocking is more prominent compared to result of increase in D_1 . The main reason is that D_2 is the probability of multiple burst retransmission attempts where as D_1 is just one time retransmission and thus has higher effect on generated network traffic than D_1. The retransmission variables can be dynamically selected for achieving minimum BLP and improved path blocking against extra load generated due to retransmission.

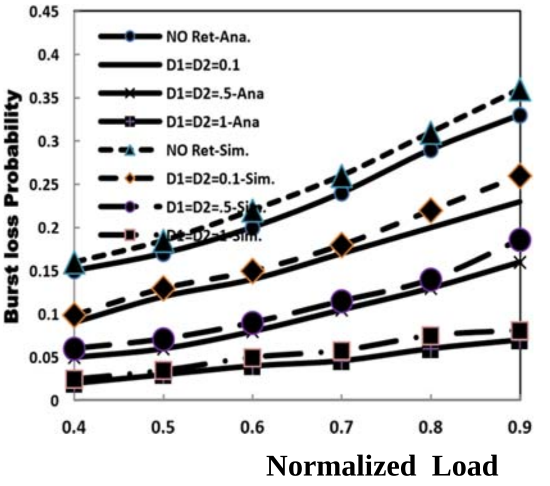

Fig-4 BLP against normalized load without wavelength conversion

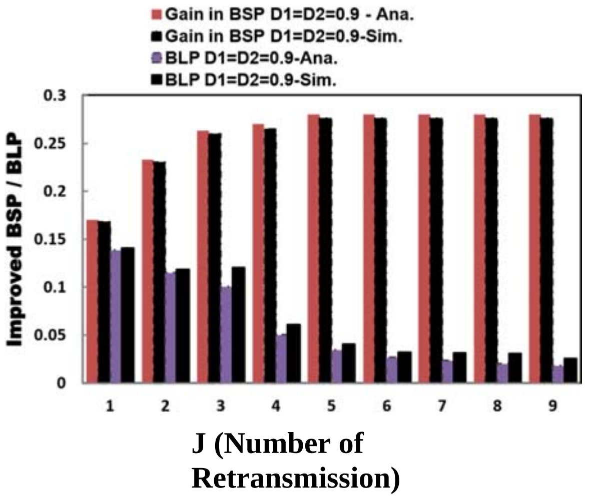

Fig- 5 Improved BSP / BLP against J in a network (Normalized load at 0.6).

(C) THE EFFECT OF DYNAMIC BURST RETRANSMISSIONS ON NETWORK PERFORMANCE

The graph in Fig.7 shows total improved BSP against varied values of retransmission attempts, D1 and D_2. When J greater than four at D_1, D_2 are 0.5 and 0.9, there is no further improvement in total BSP. Also, with increase in extra load

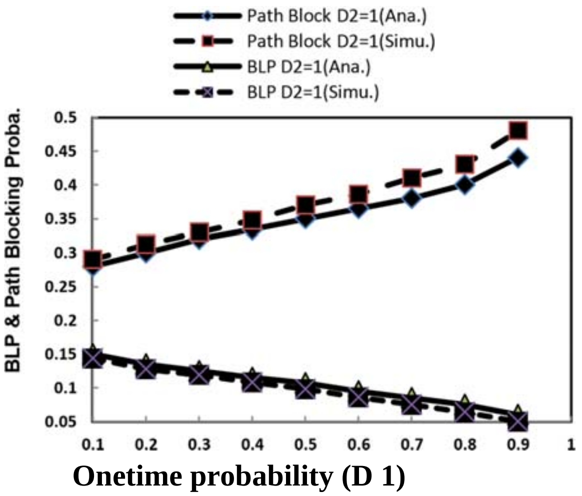

Fig. 6 Effect of D1 on the network performance (D2 = 1)

The graph in Fig.7 shows total improvement in BSR against varied values of retransmission attempts, P1 and P2. We have taken the *N* is four at P1=0.4, P2 = 0.5 for three consecutive attempts. We observed that our proposed scheme provides drastic improvement in BSR compared to existing scheme at high load. This is due to fact that our hybrid scheme performed effective wavelength assignment and converter during heavy contention period than simply retransmissions. The value of BSR is reduced at very high load (above 0.7) in existing scheme and there is constant increase in BSR in our proposed scheme. When network load become very high, the benefits associated with our scheme is clearly visible than the constant increases in path blocking in case of existing scheme even at lower values of *N*. Thus, by observing the results carefully the optimum combination of P1, P2 and N can be dynamically selected for achieving improved BSP and path blocking in buffer less OBS network. Thus, by observing the results carefully the optimum combination of D_1, D_2 and J can be dynamically selected for achieving improved BSP and path blocking in OBS network. The simulated results closely match with analytical results and thus it is validated.

The Fig. 8 shows the variation in the throughput against increasing load for varied D_1 and D_2. At high value of D_1 and D_2 , the throughput gradually reduces due to extra load in network but it increases because improved BSP associated with higher retransmission variables. When D_1 and D_2 equal to 0.9, the throughput slightly fall rather than rapidly with increased in load. Thus, concept of dynamic burst retransmission proves to be effective.

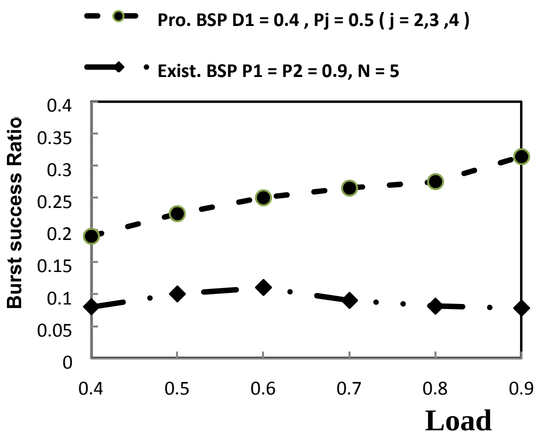

Fig. 7 Gain in BSP for a network without wavelength conversion.

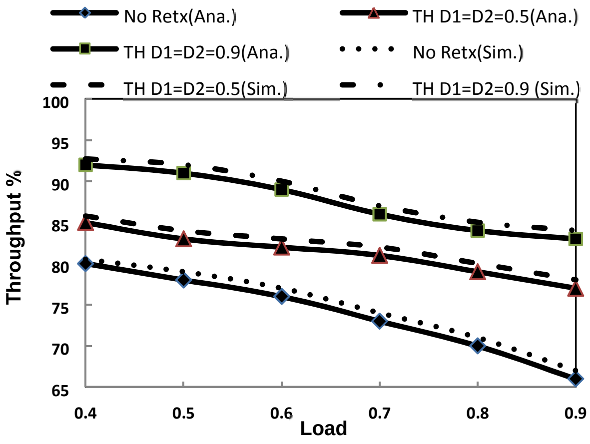

Fig. 8 Over all throughput in a network at J = 4.

VI. CONCLUSION

In general, the retransmission of the lost bursts improves the contention loss. But, the random burst retransmission generates extra load and BLP with missing the very aim of retransmission. In the case of TCP traffic the retransmission after certain time period is meaningless. To resolved, the adaptive burst retransmission mechanism ABRM proposed and analyzed. It includes retransmission variables that can dynamically control the rate of burst retransmission and extra load in the network. The investigated results clearly show that the value of D_1, D_2 and J can be selected for reducing the network load associated with burst retransmission and thus BLP. The analytical model is presented for computing the exact value of arrival rate and actual load due to burst transmission and retransmission. Also, the performance metrics prepared for measuring the performance gain associated with proposed DBRM scheme and its effects on overall network performance. The outcome of our work suggest that even at high load(more than 0.7) the ABRM scheme with higher values of retransmission variables(D_1=D_2=0.9) offers better perform for improved BSP and throughput.

Our proposed scheme ABRM is validated against vBSN network topologies and its results compared with no retransmission scheme. Ours proposed framework can be potentially utilized for selective burst retransmission to manage quality of service constraint in the network where, the BLP and path blocking can be minimized by adaptive tuning of D_1, D_2 and J.

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