A new prediction method at the edge of optical burst switching network

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To achieve lower assembly delay at optical burst switching edge node, this paper proposes an approach called current weight length prediction (CWLP) to improve existing estimate mechanism in burst assembly. CWLP method takes into account the arrived traffic in prediction time adequately. A parameter 'weight' is introduced to make a dynamic tradeoff between the current and past traffic under different offset time. Simulation results show that CWLP can achieve a significant improvement in terms of traffic estimation in various offset time and offered load.

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Optical burst switching (OBS)[1] combining the advantage of both circuit switching and packet switching and avoiding their shortcoming has gained a lot of attention recently. OBS is one of the most promising switching paradigms in the design and implementation for the optical backbone IP over dense wavelength division multiplexing (DWDM) networks. The assembly edge nodes and optical switching core nodes compose the OBS network. The assembly nodes connect legacy interfaces such as Ethernet, asynchronous transfer mode (ATM), synchronous digital hierarchy (SDH) and IP routers to core nodes. Many one-way reservation approaches, such as just enough time (JET) have been applied to OBS that reduce signaling delay and allow accessing to bandwidth in fractions of wavelengths which improves the bandwidth utilization. In JET, a source node sends a control packet and then starts burst transmission after an offset time without receiving any acknowledgement from egress edge node. Using extra information to better predict the start and the end of the burst, a wavelength is reserved efficiently to transmit the burst. Burst assembly and JET-based offset time management policy are two important issues in OBS network. In Refs. [2,3], burst assembly and offset time introduce extra electronic buffer delay called assembly delay. The total assembly delay of an optical burst is the sum of buffering time for all electronic packets from arrival to packet transmission. An optical burst must wait assembly time and offset time to transmit which is too large compared to end-to-end propagating delay. This decreases the utilization of OBS network drastically and loses the guarantee for the high priority service. Electronic assembly delay at edge node exerts a deteriorative influence on core network. Therefore, it is very significant to present an effective burstification scheme to reduce the assembly delay.

The first research about delay reduction at burst assembly of edge node is based on traffic linear prediction in Ref. [4]. Then Ref. [5] uses the linear prediction method named normalized minimum mean square error prediction (MMSEP) to OBS network that facilitates the burst delay reduction functionality. Reference [6] gives a simple traffic estimate method which only calculates the estimate burst length by current arrival traffic. We refer to this method as current length prediction (CLP) here. However the prediction precision of the existing method fluctuates with the offset time and assembly time and the prediction methods may generate large estimate error, which deteriorates the performance of OBS network extremely. In this paper, we propose a new prediction method for self-similar traffic called current weight length prediction (CWLP) to improve existing estimate mechanism in burst assembly. CWLP method takes into account both the current arrived traffic in prediction time and past burst length adequately. A parameter 'weight' is introduced to make a dynamic tradeoff between the current and past traffic under different offset time.

Our prediction system model employs JET protocol. Burst assembly time lies on many factors consisting of the number of accessing sources, the offered load, service classes, bit rate and network capacity etc. Moreover assembly time decides the burst length size too. In view of current optical switching and control packet processing speed, offset time that ranges from several hundred microseconds to millisecond magnitude is almost the same as assembly time. In the traditional OBS system, edge node will not send control packet until the whole burst generates, as shown in Fig. 1(a). Then after an offset time, burst is sent to the OBS network.

Figure 1(b) depicts the CWLP method, in which every burst can reduce the delay of an offset time. The prediction time and offset time comprise burst assembly time. The black packets denote the actual arrived traffic during prediction time, and the grid packets represent the predicting traffic that will arrive in offset time. Each burst length is estimated in the prediction time according to the past p-order burst length value and current arrived traffic. At the end of prediction time, edge node estimates the burst length and sends control packet to

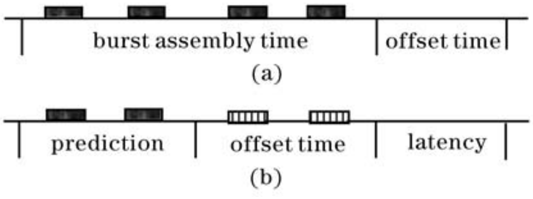

Fig. 1. Edge node assembly and offset time models.

core network. When assembly is over, we compare the estimate value with the actual burst length value and obtain the length estimate error.

Multiple self-similar traffic sources access OBS ingress edge node, and then different packets from every source are classified into each burst queue for electronic buffer in terms of quality of service (QoS) priority and output port. CWLP method is applied in each burst queue. Burst length estimation is executed as described in Fig. 1(b). Since only the burst length estimation is considered, the estimate error last time has no effects on the next actual burst length at this queue. For example, if estimate length is smaller than actual burst size, the residual packet will not be appended to the next burst queue. We only study the prediction performance of different method under self-similar traffic.

Based on MMSEP algorithm for self-similar traffic described in Ref. [7], CWLP method interpolates a current traffic weight in prediction time to improve the estimation performance of real-time traffic. We consider the following three steps to explain the CWLP method.

Step 1: The first packet arrival at the corresponding port and service class assembly queue triggers the related adaptive auto-regressive (AAR) linear filter. Simultaneously, the previous prediction value of burst length $L(n)$ is used to calculate the error $e(n) = l(n) - L(n)$ and weight $w(i)$ $(i = 0, \cdots, p-1)$ in Eq. (2). Afterward, burst assembly queue passes the current arrival traffic $l(n+1)$ to AAR filter.

Step 2: CWLP calls the past p-order burst length value $l(n-I)$, $I = 0, \cdots, p-1$, and combines $w(i)$ with current arrival traffic $l(n+1)$ to estimate the burst length $L(n+1)$. Expressions (1) and (2) give CWLP one-step burst length prediction value $L(n+1)$. The $w(-1)$ is the weight of current arrival traffic $l(n+1)$ related to assembly time T_{a} and current prediction time $T_{\mathrm{a}} - T_{\mathrm{o}}$ (T_{o}: offset time). The coefficients $w(i)$ are initialized to variable weight, $i = 0, \cdots, p-1$ and α to 1-weight in Eq. (1). Set μ to 1 for a fast convergence in Eq. (2).

$$\begin{aligned} L(n+1) &= \sum_{i=0}^{p-1} w(i) l(n-i) + \alpha l(n+1) \frac{T_{\mathrm{a}}}{T_{\mathrm{a}} - T_{\mathrm{o}}} \\ &= \sum_{i=-1}^{p-1} w(i) l(n-i), \end{aligned} \tag{1}$$

$$\vec{w}(n+1) = \vec{w}(n) + \frac{\mu[l(n) - L(n)]\vec{l}(n-1)}{\left\| \vec{l}(n-1) \right\|^2}. \tag{2}$$

Step 3: CWLP sends control packet with $L(n+1)$ at the end of the prediction time. When the data burst assembly completes, CWLP calculates length error and SNR^{-1} according to estimate size $L(n+1)$ and actual size $l(n+1)$. Then the performance of burst assembly estimate is compared with other prediction methods.

We perform simulations in a network environment, along with the following assumptions: 1) Forty 100-Mb/s Ethernet sources as described in Ref. [8] access the edge node. Hurst parameter of packet inter-arrival process is 0.9; 2) every self-similar source generates packets of which the length follows Pareto distributed with the range from 64 to 1518 bytes. The shape parameter of Pareto distribution is 1.4 (i.e. Hurst = 0.8); 3) we use four service classes to stand for different priority traffic. The number of egress edge nodes is 15; 4) burst assembly time is 1 ms. The order of the AAR linear filter is four.

The accuracy of MMSEP, CLP and CWLP method is assessed by the parameter: $\mathrm{SNR}^{-1} = (\sum e(n)^2)/(\sum l(n)^2)$ which is the inverse of signal-to-noise ratio (SNR). As shown in Fig. 2, we first study the relation of SNR^{-1} to offset time under MMSEP, CLP and CWLP method. When load = 0.8, the SNR^{-1} of MMSEP is 0.165673 larger than CWLP all along but smaller than CLP in the case of $T_{\mathrm{o}} > 0.7$. This demonstrates that large offset time deteriorates CLP estimate performance drastically. We also can see that when T_{o} is less than 0.6, SNR^{-1} of CWLP is close to CLP while CWLP is much better than CLP if $T_{\mathrm{o}} > 0.6$.

Secondly, the dependence of SNR^{-1} on offset time and weight in CWLP with load = 0.8 is simulated (Fig. 3). The bar plot indicates that SNR^{-1} becomes larger along with the offset time increased. Meanwhile inside the same offset time, SNR^{-1} changes with weight and has an optimal value. Through comparison, it is easy to find out that the minimum value appears at the range from weight $= 0.8T_{\mathrm{o}}$ to weight $= 0.9T_{\mathrm{o}}$, $T_{\mathrm{o}} = 0.2$, 0.5, 0.6, 0.7, and 0.8.

Finally, SNR^{-1} versus different load is described in Fig. 4. When offset time is small such as 0.2 in Fig. 4(a), the performance of MMSEP is worst and CLP is a little better than CWLP. However, CWLP is better than MMSEP and the SNR^{-1} of CLP is the highest when offset time is 0.8. From the above simulation results, we can conclude

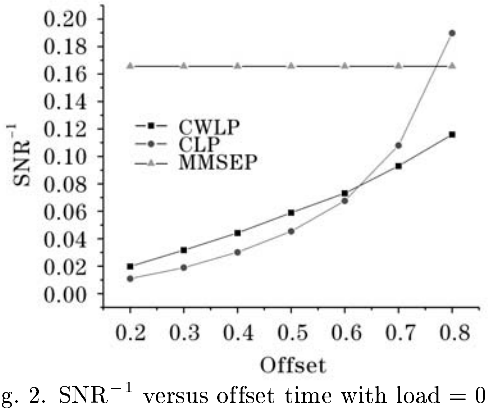

Fig. 2. SNR^{-1} versus offset time with load = 0.8.

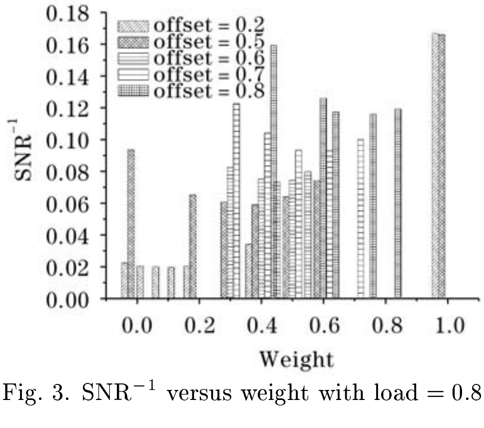

Fig. 3. SNR^{-1} versus weight with load = 0.8.

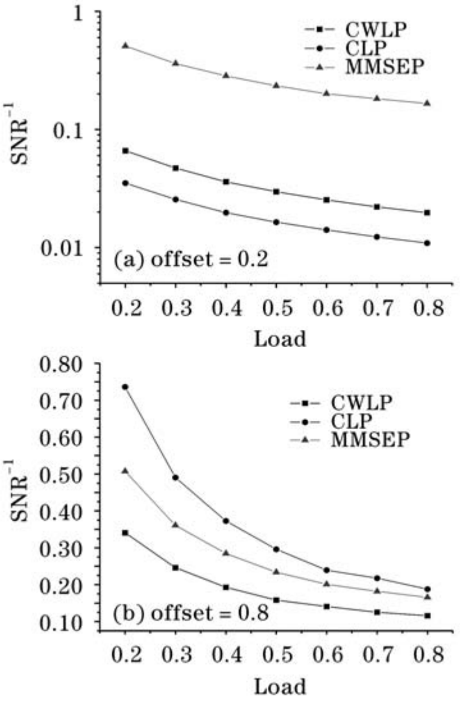

Fig. 4. SNR^{-1} versus load comparison.

that whatever the ratio of offset time to assembly time is, the CWLP method can execute effective estimation for the self-similar traffic. The parameter 'weight' makes a dynamic tradeoff between the current and past traffic under different offset time. The performance of CWLP is better than that of CLP and MMSEP as a whole. Because the real Internet traffic is self-similar process now, CWLP is flexible by selecting a certain weight and most suitable for optical network and Internet.

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References

1. C. Qiao and M. Yoo, J. High Speed Networks **8,** 69 (1999).
2. Y. J. Xiong, M. Vandenhoute, and H. C. Cankaya, IEEE J. Sel. Areas in Commun. **18,** 1838 (2000).
3. A. Ge, F. Callegati, and L. S. Tamil, IEEE Commun. Lett. **4,** 98 (2000).
4. D. Morató, J. Aracil, L. A. Díez, M. Izal, and E. Magaña, in *Proceedings of ICCCN 2001* 138 (2001).
5. J. Liu, N. Ansari, and T. J. Ott, IEEE J. Sel. Areas in Commun. **21,** 1210 (2003).
6. T. Hashiguchi, X. Wang, H. Morikawa, and T. Aoyama, in *Proceedings of COIN/ACOFT 2003* 664 (2003).
7. A. M. Adas, IEEE/ACM Trans. Networking **6,** 635 (1998).
8. W. E. Leland, M. S. Taqqu, W. Willinger, and D. V. Wilson, IEEE/ACM Trans. Networking **2,** 1 (1994).