Design of assembly control algorithm based on burst-size feedback for optical burst switching network

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A novel assembly control algorithm named burst-size feedback adaptive assembly period (BFAAP) is proposed. The major difference between BFAAP and other similar adaptive assembly algorithms is that the control curve of BFAAP is dynamically adjusted according to the feedback of outgoing burst size. BFAAP is compared with two typical algorithms fixed assembly period (FAP) and min-burst length max-assembly period (MBMAP) in simulation in terms of burst size distribution and assembly period. Moreover, the transmission control protocol (TCP) performance over BFAAP is also considered and simulated.

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Optical burst switching (OBS) has been introduced to combine both strengths of optical packet and circuit switching and been considered as a promising paradigm for the next generation optical Internet[1−8]. In the OBS networks, burst assembly plays an important role because it significantly affects the characteristics of the incoming network traffic. Moreover, it also affects the burst loss probability and burst transmission delay[1−4]. Several burst assembly algorithms have been proposed and most of them can be classified into time-threshold based burst assembly algorithms and size-threshold based burst assembly algorithms. Nearly all of those assembly algorithms can be considered as an open-loop system, although some adaptive threshold algorithms may change the thresholds according to the traffic flows. And usually, useful feedback data such as the burst size cannot be acquired by the assembly algorithms, except for a few size-threshold based burst assembly schemes. In general, the burst size distribution is however considered as a key factor to affect the performance of scheduling modules as well as the burst loss probability[2−4].

The structure of OBS edge node is shown in Fig. 1 and consists of three modules. The Addr classifier is used for it forwarding the incoming Internet protocol (IP) packets to the corresponding back-propagation (BP) agent according to their destination address, and by contrast, the Port classifier will assign the burst packets whose destination address is just the edge node address to the corresponding BP agent. BP agent is the key component in which the IP packets will be assembled into burst packets or the burst packets be disassembled to IP packets.

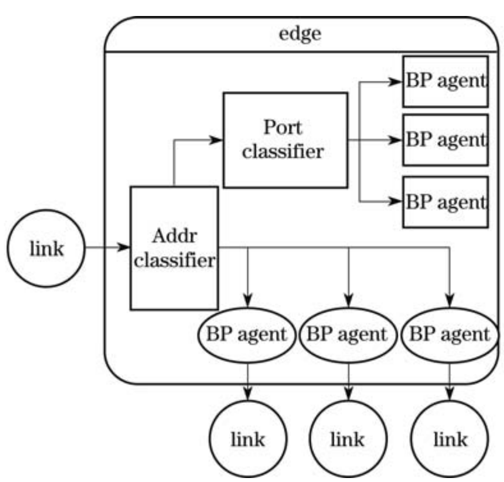

Fig. 1. Structure of OBS edge node.

In this letter, a novel assembly control algorithm named burst-size feedback adaptive assembly period (BFAAP) is proposed to accomplish the assembly function of BP agent. The block diagram of BFAAP is shown in Fig. 2. The assembly queue (AQ) is regarded as the control object, while the assembly timer (AT) is regarded as the executor. Assembly controller (AC) periodically measures the increasing rate of IP packets in the buffer and chooses a suitable assembly period for AT according to the control curve. Then AT will instruct AQ to acquire the IP packets from the buffer and assemble these IP packets into burst packet. When the burst is finished and the corresponding burst control packet (BCP) is sent out, AQ will inform AC of the burst size and AC is probably to adjust the control curve according the changing rate of burst size. Therefore, the assembly control algorithm has been changed to a closed-loop system.

BFAAP is basically a time-threshold based assembly algorithm. It aims to control the burst size distribution by adjusting the assembly period (AP) according to the on-line traffic flow. The major difference between BFAAP and other similar adaptive assembly algorithms is that the control curve of BFAAP is dynamically adjusted according to the feedback of outgoing burst size, which is more flexible than the algorithms whose adjusting parameters are fixed. An example of control curve adopted by BFAAP is shown in Fig. 3. The control curve is actually the function of the assembly time threshold and maximum increasing rate of IP packets. As the maximum increasing

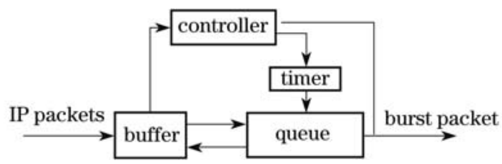

Fig. 2. Block diagram of BFAAP.

rate of IP packets increases, the assembly time threshold monotonously degrades.

Let T_s denote the sampling period of IP packets in buffer and Num(i) denote the number of IP packets during the ith sampling period. Then, the maximum increasing rate of IP packets denoted by Max_num can be calculated as

$$\begin{aligned}\text{Max\_num} = \; & \text{Max}\big\{\text{Num}(1), \text{Num}(2) - \text{Num}(1), \cdots, \\ & \text{Num}(i+1) - \text{Num}(i), \cdots\big\}.\end{aligned}$$

Considering the inevitable delay when AQ assembles the IP packets into burst packet, the sampling period has to obey the following constraint: $\sum\limits_{i=1}^{N} T_\mathrm{s} < T_{\min}$, where N denotes the sampling times and $T_{\min}$ is the minimum of assembly time threshold.

The assembly time threshold which determines the AP has both lower bound $T_{\min}$ and upper bound $T_{\max}$. The lower bound is determined by the queuing delay of BCP as well as the number and bandwidth of control channels[1,6]. The upper bound is determined by the transmission control protocol (TCP). For a specific TCP flow$f$, in order to prevent TCP from unnecessarily (or prematurely) retransmitting packets in the burst, AP should not be greater than the retransmit timeout value (RTO) minus the round trip time (RTT) value associated with flow$f$[1,5,6]. Therefore, $T_{\max} = \min\limits_{f}(\text{RTO} - \text{RTT})$. Let T_step denote the adjusting step of assembly time threshold. $T_\text{step} = (T_{\max} - T_{\min})/M$, where M is the number of total steps.

Let Δb_size denote the change of current burst size compared with former burst size and R denote the changing range of burst size. The control curve will be adjusted according to the following rules: if $\Delta b_\text{size} < -R$, then AP $=$ AP $+ T_\text{step}$; and if $\Delta b_\text{size} > M$, then AP $=$ AP $- T_\text{step}$. The arrows and dotted lines in Fig. 3 illustrate the adjusted results.

In order to evaluate the effect of the burst assembly

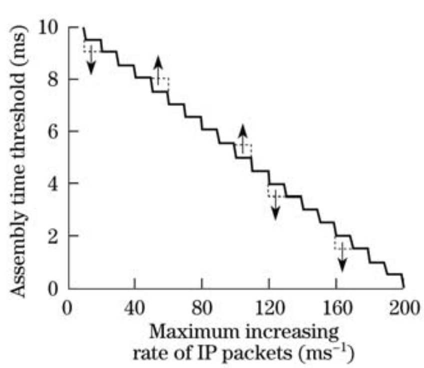

Fig. 3. Example of control curve between maximum increasing rate of IP packets and assembly time threshold.

algorithms under investigation on TCP performance, the BFAAP algorithm and the fixed assembly period (FAP) and min-burst length max-assembly period (MBMAP) algorithms are simulated in the network shown in Fig. 4. There are three edge nodes and six TCP agents in the network. The TCP agents send out IP packets randomly and the size of each TCP-Reno connection follows a Pareto distribution with shape parameter α= 1.2 and mean size of 40 kB.

Figure 5 shows the simulation results of burst size distribution for FAP, MBMAP, and BFAAP. The AP of FAP and MBMAP is set to 10 ms. As shown in Fig. 5, the distribution of burst size assembled by FAP changes in a large range. MBMAP performs better than FAP due to the constraint of min-burst length. BFAAP outperforms both FAP and MBMAP and the burst size distribution is limited to a smaller range.

Figure 6 shows the simulation results of AP for FAP, MBMAP, and BFAAP. FAP has a fixed AP while MBMAP can change AP when the burst size reaches the min-burst length. BFAAP can dynamically change AP according to the traffic flow.

Figure 7 shows the simulation results of good-put under TCP connection for FAP, MBMAP, and BFAAP.

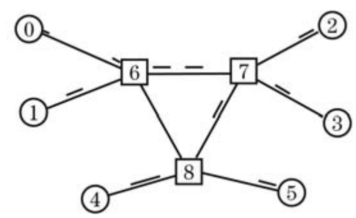

Fig. 4. Simulation network.

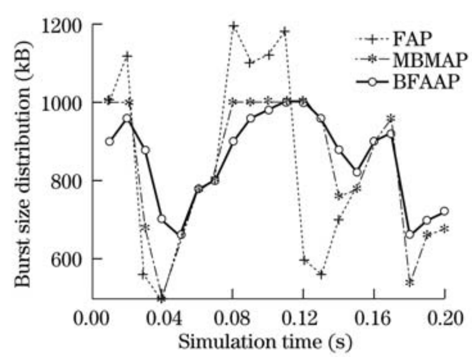

Fig. 5. Simulation results of burst size distribution for FAP, MBMAP, and BFAAP.

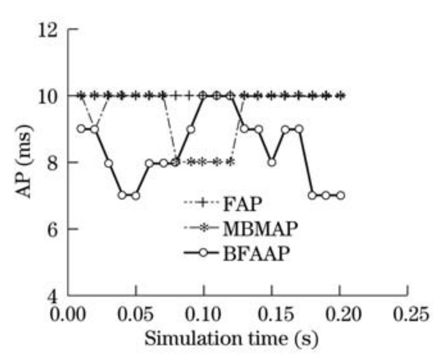

Fig. 6. Simulation results of AP for FAP, MBMAP, and BFAAP.

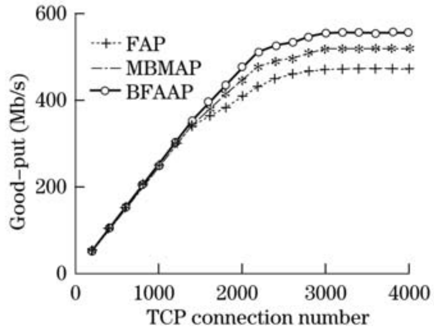

Fig. 7. Simulation results of good-put under TCP connection for FAP, MBMAP, and BFAAP.

BFAAP outperforms both FAP and MBMAP, especially for a large number of TCP connections. BFAAP adjusts the AP properly and synchronizes with TCP congestion control mechanism, and thus enhances the TCP good-put performance.

In conclusion, the proposed algorithm of BFAAP outperforms both FAP and MBMAP on the performance of burst size distribution in simulation. In the case of TCP connections, BFAAP can dynamically change AP according to the traffic flow and therefore get better good-put performance than FAP and MBMAP.

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