A Novel Proportional Window based Dynamic Bandwidth Allocation Algorithm in Optical Network

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Abstract. Dynamic bandwidth allocation (DBA) algorithm for the passive optical networks (PON) is a key issue for network planner. There are always various constraints during the bandwidth allocation process, so that it can be regarded as a multi-object mathematic problem. In this paper, we have proposed a novel proportional window based bandwidth allocation algorithm that considering service QoS requirement. We mainly arrange more bandwidth for higher level service. Finally, we establish a simulation platform to verify the proposed approach, and the result show that it outperforms traditional static bandwidth allocation approach and the mostly used interleaved polling with adaptive cycle time approach especially for the higher grade service.

Introduction

The increasing bandwidth in the backbone network have presented new requirement for traffic engineering technology and IP QoS service model, so as to solve the problem of bandwidth allocation considering the grooming IP traffic^[1,2]. In order to guarantee the quality of dynamic service flow, the SLA is quite useful to provide flexibility for traffic access. GPON-based transport hierarchy (GTH) is now commonly used in the access network, including the traffic layer, transport layer and physical layer^[3,4]. G-PON transmission convergence frame is used to assign bandwidth, and the corresponding T-CONT frame is encapsulated with specified length to carry the new arrived data. Different service type (i.e., TDM, ETH, or private line) will map the service to the unified GEM frame, and identified the traffic flow with source and sink address⁰. For the bandwidth allocation in GTH, OLT is responsible for the bandwidth requirement collection and the overall bandwidth assignment for each ONU. As each ONU is separated, there will not be any overlapped bandwidth⁰. The primary node is a common node with specific function, while it is the controlling algorithm manager. The bandwidth allocation and release shall be management by the primary node, so that the released bandwidth can be used by extra service flow.

G. Kramer has proposed a bandwidth allocation algorithm named Interleaved Polling with Adaptive Cycle Time (IPACT), and it is now widely used in the centralized managed network⁰. The bandwidth usage information is transmitted through a polling approach to solve the fixed time slot shortage. The OLT works in round-robin mode and send polling command to each ONU separately. The ONU receive data in the authorized window. The buffer length in ONU is controlled by OLT, and it takes direct effect on the next round bandwidth allocation. The global round-robin time is maintained by the central OLT, during the allocating process, the consecutive frame is separated with a guaranteed time period. The data frame is not constraint whether in a sequential manner or a synchronized transfer scheme. The GPON network supports a mix of services with different bandwidth requirement, DBA algorithm is used to improve the resource utilization.

In this paper, we have proposed a novel proportional window based dynamic bandwidth allocation algorithm (PWDBA) to solve the fairness of each service flow, and keep the priority at a reasonable range at the same time. Also a simulation platform is constructed to verify the performance of proposed approach.

Propotional Window based Bandwidth Allocation Algorithm

Problem Illustration

Within the GTH network (or subnet), there is a main node works as master and several slave modes. The GTH main node is responsible for the bandwidth allocation of ring network. Dynamic bandwidth allocation in GTH transmission network is based on T-CONT data transmission. The data frame is managed by the centralized computing approach, and the actual business flow is controlled by the length of T-CONT frame. GTH network working process can be divided into the following three steps:

Uplink request process

Each node in the transmission network is equipped with a queue and bandwidth request information is submitted to this node (DBR).

If there is multiple business flow in the T-CONT, the service flow is identified respectively from the node according to specific service cache^[8,9]. The bandwidth request is labeled in Alloc_ID bytes. Figure 1 present the demonstration working flow of a ring network, including one master node and three slave nodes.

Fig.1 DBA working flow within a ring topology

Downlink allocation process

The speed of each slave node transmits 8000 frames per second in GTC data frame (125us period). The allocating information is directed in GTC bandwidth (BW) MAP as shown in the following diagram⁰. The position of different service is identified in the BW_MAP, and the Alloc_ID is used together with start and end position for each service flow. The BW_MAP is useful for the bandwidth allocation and shall be update if the service is removed or newly established.

Fig.2 Bandwidth allocation scheme in GTC network

Add/Drop process

When GTC frame arrived at each node, the service with a T-CONT could take add or drop operation and the T-CONT will be further de-capsulated as different GEM service. The newly added service flow will be encapsulated and request bandwidth again.

Mathetic Mode for the prototional bandwidth allocation

Assume in the N nodes ONU GTC network with line rate R_N , the service with different Qos requirement is accessed. During the k-th polling cycle, the available transmission window $W^{Total}(k)$ can be represented as,

$$W_{total}(k) = [T_C - T_{OH}(k) \times N] \times R_N \quad (1)$$

Where T_C is the polling period, $T_{OH}(k)$ denote the overhead of ONU during the k-th polling cycle. The $T_{OH}(k)$ includes the physical devices protect time, which is used to ensure that each ONU can achieve stabilized state during opening/closing process, this is mainly affected by the laser ON/OFF time, automatic gain control (AGC) and clock-and-data (CDR) recovery time^[11,12]. It should be designed properly, if too large, the transmission efficiency will be reduced. If too small, the data conflict will occurs. After data transmission, ONU will report the buffer usage to OLT with fixed period. The report information includes the overall buffer requirement and intra-ONU priority. The diff-server subgroup division shall be updated with real time approach. The weight of ONU w_i is defined as follows,

$$w_i = \begin{cases} w_H & \text{Highpriority ONU} \\ w_L & \text{Lowpriority ONU} \end{cases} \quad (2)$$

For simplicity purpose, here w_H and w_L denote two service levels of electric power service in transmission system. The subgroup H and subgroup L is used to distinguish different QoS requirement. Each ONU assign the weight according to the service type, $w_H > w_L$.

$$\begin{cases} w_H \times N_H + w_L \times N_L = w_{total} \\ N_H + N_L = N \\ \frac{w_H \times N_H}{w_L \times N_L} = \alpha_{prio} \end{cases} \quad (3)$$

N_H and N_L represent the number of high priority ONU and low priority ONU respectively. Finally, we use α_{prio} to denote the ratio of different service type.

By setting the value of ONU weight, the ONU no longer need to assign a maximum transfer window anymore, the guaranteed ONU window size can be set proportionally. However, the minimum authorized window $G_i^{\min}(k)$ shall be set with the following equation.

$$G_i^{\min}(k) = \min \begin{cases} \frac{w_i}{w_{total}} \times W_{total}(k) \\ R_i(k) \end{cases} \quad i \in I \quad (4)$$

In which, $R_i(k)$ denote the requested window of ONUi in the k-th cycle. The rest of the bandwidth is used for the secondary level service and the lowest priority, and thus the fairness and the priority can achieve a reasonable proportion.

The minimum guaranteed window is not always equals tot the last transmission window size especially that $R_i(k)$ is less than the proportional bandwidth. The secondary bandwidth allocation process can be compute as,

$$\sum_{i \in I} \left(\frac{w_i}{w_{total}} \times W_{total}(k) - G_i^{\min}(k) \right) \quad (5)$$

If the summation of incremental bandwidth requirement and residential bandwidth is more than high priority service requirement, there could be a remaining bandwidth for the low level service. Otherwise, the high level service bandwidth is allocated as,

$$\frac{R_i(k)}{\sum_{i \in H} R_i(k)} \times \min \left\{ \sum_{i \in H} (R_i(k) - G_i^{\min}(k)), \sum_{i \in L} \left(\frac{w_i}{w_{total}} \times W_{total}(k) - G_i^{\min}(k) \right) \right\} \quad (6)$$

By distinguishing service priority, the DBA bandwidth allocation process can be written as,

$$G_i(k) = \begin{cases} G_i^{\min}(k) + \frac{R_i(k)}{\sum_{i \in H} R_i(k)} \times \min \left\{ \sum_{i \in L} \left(\frac{w_i}{w_{total}} \times W_{total}(k) - G_i^{\min}(k) \right), \sum_{i \in H} (R_i(k) - G_i^{\min}(k)) \right\} \\ (i \in H) \\ G_i^{\min}(k) + \frac{R_i(k)}{\sum_{i \in L} R_i(k)} \times \min \left\{ \left[\sum_{i \in L} \left(\frac{w_i}{w_{total}} \times W_{total}(k) - G_i^{\min}(k) \right) - \sum_{i \in H} (R_i(k) - G_i^{\min}(k)) \right], 0 \right\} \\ (i \in L) \end{cases} \quad (7)$$

Using two levels of scheduling strategy, the intra-ONU scheduling and inter-ONU scheduling are combined together with the polling process. OLT establish and maintain a subgroup distribution table according to the ONU's REPORT. The bandwidth resource of high level and low level service group can be updated with real-time bandwidth usage. As the report from ONU includes both transmission window size and the intra queue usage, the high level service is categorized in the H group while the BE type service is categorized in the L group. If a high level service appears, it is registered by the REPORT frame, and the OLT will update subgroup table. The bandwidth is previously prepared for the higher level service. After data transmission, the ONU will be set back to the L group in order to avoid the unfair competition for extra bandwidth allocation. The proportion of bandwidth for different type of service is controlled by the parameter of α_{prio} .

Experimental Results

In order to demonstrate the performance of the proposed algorithm, we have established a simulation platform (as shown in figure 3), including the controlling center, and there are multiple service flows access the ring network. The detail parameters are listed in Table I.

Fig.3 Simulation platform of the GTC transmission

Parameter	Value
Line rate	1Gbps
ONU data rate	100Mbps
Number of ONU	16
Distance between OLT and ONU	20km
Number of ONU priority queue	3
Guaranteed bandwidth	5us
ONU Buffer	1Mbytes
Polling period	2ms
Frame length	64~1518bytes

Table I Simulation Parameters In The Demonstration GTC Network

Figure 4~6 presented the simulation results of the three typical bandwidth allocation algorithms. G1, G2, G3 denote the three different service level. In which G1 is the highest level service and G3 is the lowest. From the results, we can conclude that the performance of G1 is the best, and the average time delay can illustrate the packet dispatching priority. However, the performance of IPACT is worse than SBA, as the IPACT require non overlap bandwidth allocation in the service flow, while the higher level service cannot take preemption within the lower level bandwidth. There is about 0.2s different at full traffic load.

Fig.4 Average time delay for the G1 group service

From the results in figure 5, we can see that the average time delay of WPDBA is a little bit higher than G1 group. The performance of PWDBA is also better than that of SBA and IPACT. While on the other side, the performance of IPACT is better than SBA. This is due to the fact that IPACT use interleaving polling scheme while it is quite flexible compared with SBA in the higher load scenarios.

Fig.5 Average time delay for the G2 group service

For the service group G3, the traffic flow of the three algorithms experience rapidly increasing of the average time delay after the 50% ONU load factor. For the G3 group, the PWDBA present a higher time delay after 60% load factor. The proportional window in PWDBA use more bandwidth for G1 and G2 group by preemption and thus few available bandwidths is left for G3 group and the

disadvantage appears for higher traffic load scenarios. The performance of PWDBA is still better for light load case.

Fig.6 Average time delay for the G3 group service

Summary

In this paper, we have proposed a novel proportional window based bandwidth allocation algorithm that considering service QoS requirement. We mainly arrange more bandwidth for higher level service. The performance of PWDBA shows that it works better if the traffic load factor is less than 0.5. The most of delay part is from the OLT polling delay and bandwidth allocation process. In practical network, the each ONU have the same weight for the initial stage and the dynamic weight can be updated during network operation procedure. The G1 group and G2 group also have competition relation, in order to avoid unnecessary for the higher level service, we have divided the bandwidth allocation into two stages to grantee the bandwidth for higher level service. In the further work, the bandwidth shall be designed with multiple service level corresponding to the service type or even more than that, so as to achieve finer regulation capability.

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