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Novel bandwidth allocation with quota-based excess-distribution algorithm and wavelength assignment in multi-wavelength access network

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ABSTRACT

Dynamic bandwidth allocation (DBA) is of great importance and interest to multichannel passive optical networks (PONs). It plays a crucial role in efficiently and fairly allocating the bandwidth among all users. In this paper, a novel quota-based excess-distribution algorithm which can achieve accurate bandwidth allocation for end-users by using Computational Theory of Perceptions (CTP) has been proposed. To manage resources efficiently, we first present a mathematical model of bandwidth allocation based on matrix theory. Then, the quota-based excess-distribution algorithm is proposed and the excess distribution quota obtained from the algorithm is adjusted in real time and adaptively to further augment the efficiency and fairness of DBA. Thus, the excess distribution becomes more centralized and independent. The proposed algorithm can effectively prevent excess distribution from bandwidth monopolization and over-allocation. Besides, we formulate a wavelength assignment mechanism based on release time to eliminate the idle period and increase the bandwidth utilization of the network. Finally, we conduct detailed simulation experiments to research and analyze the performance in terms of delay, bandwidth utilization and fairness among ONUs. The simulation results demonstrate that at least 8.5% bandwidth utilization improvement and low average delay are achieved compared with other schemes and the fairness index keeps almost constant and is close to 1 in the proposed scheme.

1. Introduction

Passive optical networks (PONs) have emerged as an attractive broadband access solution to meet the increasing demand of bandwidth from various services [1,2]. At present, the PONs are mainly based on TDM (time-division-multiplexing) such as EPON and GPON [2]. However, the bandwidth provided for each end-user is limited. The wavelength-division-multiplexing (WDM) technology has extensively been studied in academics and industries as a promising approach to meet huge-bandwidth communication [3,4]. Due to the large coverage area and easy upgrade, the PON architecture with topology of ring and trees as showed in Fig. 1 is becoming the trend for large-scale passive optical networks [5]. The ring-tree network is comprised of one OLT (optical line terminal), M RNs (remote nodes) and N ONUs (optical network units). All the RNs are connected to the OLT in the ring topology and the ONUs are attached to each RN. Here, Nx ($x=1, 2, 3\ldots M$) is defined as the number of users connected with the x-th RN. RN consists of circulators, couplers, wavelength blockers (WB) and 1M AWGs (arrayed waveguide gratings).

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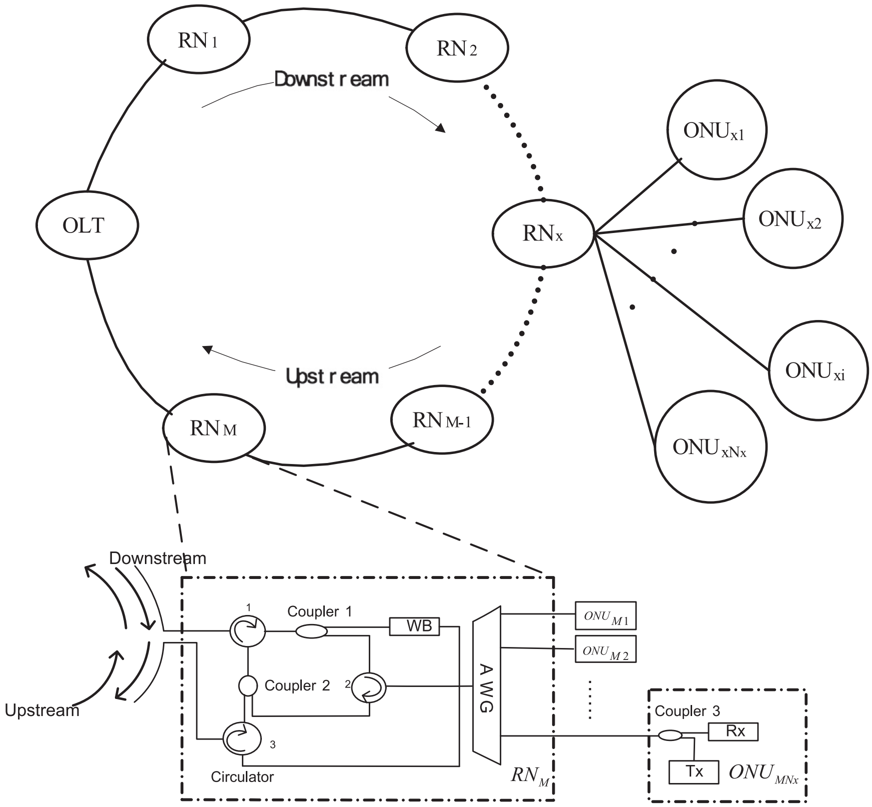

Fig. 1. Architecture of multi-wavelength access network.

The complex signals for multiple wavelengths are transmitted from one RN to another RN in turn. Specially, the downstream signals are delivered from RN_1 to RN_M and the upstream signals are delivered from RN_M to RN_1. The transmission route is realized by the configuration of RN. Here, we take RN_M, for example, to explain the operation principle. The OLT is equipped with transmitters and receiver arrays to transmit data or control messages to the ONUs and receive data from the various ONUs. The downstream signals get into RN_M through the fiber and they are routed to the coupler1 by circulator 1. Then, the signals are divided into two parts. One part is directly sent to an AWG and a set of them will be de-multiplexed for each ONU. The other part is sent to a WB to enable the wavelengths for other RNs to pass, and they will be sent to the feed fiber through circulator 3 for other RNs' downstream transmission. A fast tunable laser with a tuning speed in the range of micrometers and a tuning range of 60 nm is installed in every ONU to enable the ONU to instantly switch from one wavelength to another. Statistical multiplexing can be realized in both wavelength and time domains. In such a multi-wavelength access network based on WDM technology, each user can be assigned one or more wavelengths to meet its bandwidth requirements. The added flexibility and reliability of the network is obvious. However, it also brings challenges to bandwidth management and allocation.

It is known to us that dynamic bandwidth allocation (DBA) mechanism plays a crucial role in producing the best possible results of PONs and it has very important meaning in providing the utmost of network bandwidth utilization as well as high-efficiency network management and operation [6]. Various DBA algorithms have been proposed over the past several years. For multi-wavelength access network, the key design issue of DBA is inter-channel and intra-channel statistical multiplexing. The intra-channel statistical multiplexing has been researched a lot in EPON and GPON [7–10]. The intra-ONU scheduling schemes such as Deficient Weighted Round Robin (DWRR) [7], fuzzy logic-based algorithm [8], resource reservation method, and Hybrid-Linear method in 10G EPON [9] have been proposed to improve packet loss rate, jitter performance and network throughput. The authors in [10] make use of the excessive bandwidth of lightly loaded ONUs to meet the bandwidth demand of heavily loaded ONUs and they address the idle period problem by using an effective scheduling control mechanism. Most DBA mechanisms are based on the multi-point control protocol (MPCP, IEEE 802.3 ah) and follow the cycle polling principle [11,12]. Since multi-wavelength access network features multi-granularity (wavelength and time slots), the dynamic bandwidth allocation is carried out in time domain as well as wavelength domain (i.e. inter-channel statistical multiplexing). Reference [13] considered the problem of bandwidth reservation for both dedicated channels and future time slots, and introduced a Time-Wavelength Co-Allocation (TWCA) scheme to effectively improve the overall system throughput and to minimize the transfer latency