


Meeting Open Access in Ethernet PON (EPON)

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Abstract: “Open access” is a regulatory requirement in many countries mandating that the residential access network infrastructure be competitively available to service providers. We propose various Service Level Agreements  achieve fairness in *open access* EPON.


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1. Introduction

Ethernet Passive Optical Networks (EPONs) are point-to-multipoint broadband access networks. An Optical Line Terminal (OLT) at the Central Office (CO) is connected to many Optical Network Units (ONUs) at remote ends using optical fiber and passive splitter. EPON has been standardized in the IEEE 802.3ah [1]. Ethernet technology is inexpensive and ubiquitous, and hence EPON seems very promising today.

Government regulation in many countries has mandated a clear demarcation between the network operators who provide physical connectivity and transport data (eg. telephone, cable companies), and the service providers (SPs) who deliver the content and the services (eg. Internet SPs). The primary motivation is to have free-market competition between SPs, thereby making services cheap and available to end users; and also preventing monopoly by the network operator who owns the right-of-way to lay cable/fiber in a residential area. Such a framework in which users are free to choose what services they need and the corresponding SPs, and the SPs are able to solicit subscribers through independent and competing marketing efforts is known as *open access* [2].

Open access is a sustainable and profitable economic model for an expensive residential access solution such as EPON  cause the cost of deployment may be recovered from multiple SPs [3]. Many residential communities and municipalities, seeing broadband data services as a key driver for economic growth, are deploying their own fiber networks. Viewing the broadband access network as a type of infrastructure similar to a town’s plumbing/sewer system, the municipalities build and manage the infrastructure, facilitating access to broadband services, but not supplying the services themselves. *Open access* therefore is a useful framework in such cases.

In an *open access* framework, different SPs may be delivering services to same or different sets of users. This leads to the requirement of fair allocation of network resources (especially bandwidth) amongst both SPs and users. This is a significant challenge, because SPs and users are located on opposite ends of the access channel. Fairness amongst users should guarantee some minimum degree of network performance (bandwidth) to all users, so that a user with killer bandwidth applications does not starve others out of bandwidth. Similarly fairness amongst SPs should ensure fair play in terms of bandwidth allocation amongst competing SPs. In this work we investigate means of achieving fairness in an *open access* framework applied to EPON. We note that EPON is considered merely as an example due to its future promise; we strongly believe that our work may be applied to other access network technologies like APON, GPON and variants of DSL as well.

2. Fairness in an open access framework.

Residential subscriber access networks ~~which are currently deployed~~ follow a best-effort model for sharing bandwidth amongst users. The main disadvantage of a best-effort model is that the service which the user receives is dependent on the current load in the network, which in turn depends on the bandwidth requirement of other users. Hence a user can never be guaranteed some level of network performance. Although such a model has survived till now primarily because of low bandwidth demand from users, it has discouraged growth of high bandwidth application and services. The complex relationship between users, network operators and SPs has been depicted in Fig. 1. Because of such relationships, QoS aware services like Video-on-Demand (VoD) are still not available in the current Internet. Access networks are the primary bottleneck, because metropolitan and long-haul networks are usually over-provisioned and thereby lightly loaded at most times.

A solution is to try to enforce Service Level Agreements (SLAs) in the access network [4]. A typical SLA includes performance guarantees such as minimum bandwidth, maximum packet loss, maximum delay, etc. SLAs in the context of SPs which define minimum bandwidth guarantees for a SP, shall enable a SP to provide QoS aware

services. For example, let us consider SP SP_a which provides a VoD service, which would require R_a bps average bandwidth per customer. Suppose this SP negotiates an SLA providing W_{MIN} bps of guaranteed bandwidth. Then, SP_a would have a guarantee from the network operator to provide reasonable QoS to W_{MIN}/R_a users at any time on an average. If the number of users simultaneously requesting VoD from SP_a is greater than this amount, SP_a may block some of the user requests in order to provide good service to the other users already admitted into the system. Similarly, providing minimum guarantees to users will give the users reasonable services and would not starve any user out of bandwidth.

We define the following three categories of SLAs:

- Service Provider SLAs (SP SLAs) :** These SLAs guarantee minimum amount of bandwidth to SPs. Guarantees may not be over-provisioned, that is they should not exceed channel capacity. This ensures that all SLAs may be met irrespective of the network load.
- User SLAs :** These SLAs guarantee minimum amount of bandwidth to users. Guarantees may not be over-provisioned.
- Dual SLAs :** These incorporate both User and SP SLAs. Although User SLAs and SP SLAs are not individually over-provisioned, the sum of the User SLAs and SP SLAs may exceed the channel capacity. Hence it may not be possible to meet both sets of SLAs at all traffic demands. Therefore, we need to distinguish between the two sets. The *primary SLA* is defined to be the one, who's specified minimum guarantees, must be given the highest priority to be met. After the *primary SLA* has been met, the next priority is to meet the *secondary SLA*. If it is not possible to meet some *secondary SLA*'s, the objective shall be to ensure fairness in the deficits in allocation of bandwidth from the secondary SLA.

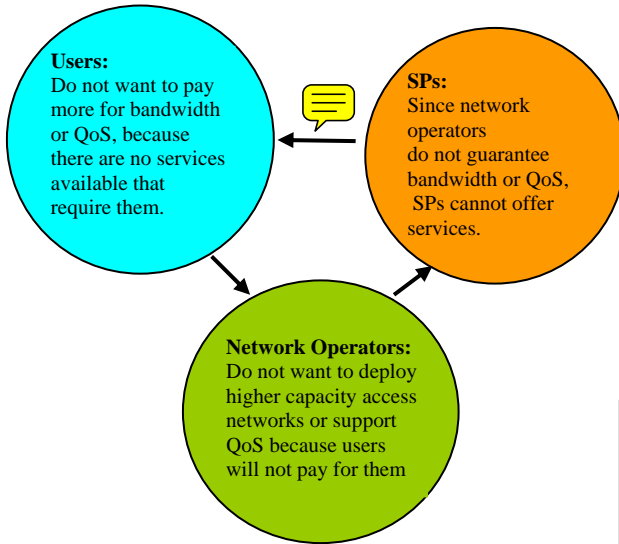


Fig. 1: Relationship between users, network operators and SPs.

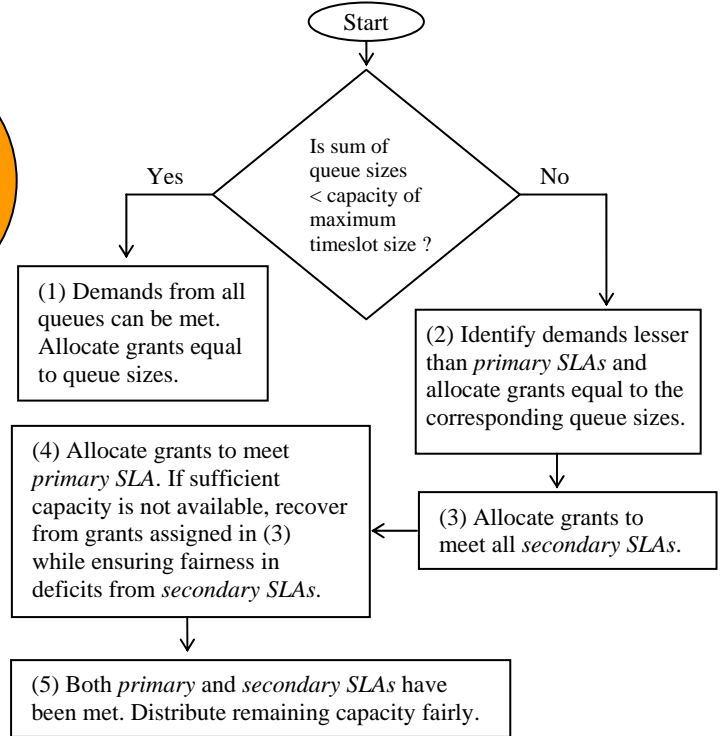


Fig. 2: Flowchart of proposed algorithm for meeting Dual SLAs

3. Implementation and illustrative numerical examples

In this paper, we consider the downstream traffic from SPs to users in an *open access* EPON system. The OLT schedules the traffic for all the users. At the OLT, there exists a queue for traffic from each SP to each user. Considering a timeslot of a fixed size, the objective is to schedule traffic from each of the queues by granting some capacity in this timeslot, keeping into consideration the SLA requirements, and distributing any surplus bandwidth after SLAs have been met fairly. This process is repeated for successive timeslots. The maximum size of the timeslot is fixed in order keep a bound on the delays. Implementing Dual SLAs is challenging because of the two different set of SLAs. In Fig. 2, we show a flowchart for our algorithm which meets Dual SLA demands. Due to the constraints of space, we do not describe the algorithm in detail here; we intend to describe it in a forthcoming publication.

We simulate an EPON system with specifications in Table 1 for the three different categories of SLAs described above. The traffic matrix is shown in Table 2. SPs 2...6 have a total traffic demand of 150 Mbps. Therefore, a fair scheme should deliver equal bandwidth to the SPs. Similarly we would expect Set III and Set IV of users to receive equal bandwidth. All traffic is generated to be self-similar with *hurst parameter* of 0.8, and with the packet size of 1512 bytes. Due to the bursty nature of Internet traffic, access networks are frequently subjected to very heavy load of traffic. Hence, in our simulations, the access network is heavily loaded at 1.39 (normalized to the line rate of 1 Gbps). We observe the performance of the EPON system for a period of 5 minutes, noting bandwidth received by each user and bandwidth allocated to each SP at intervals of 1 second. In Fig. 3 (a) and (b), we show the average bandwidths for the three different categories of SLAs.

Table 1: *Open access* EPON parameters

| Parameter | Value |
|------------------------|--|
| Rate of EPON | 1 Gbps |
| Number of SPs | 6 |
| Number of users (ONUs) | 32 |
| SP SLA | 150 Mbps per SP |
| User SLA | 25 Mbps per user |
| Dual SLA | 150 Mbps per SP (<i>primary</i>), 25 Mbps per user (<i>secondary</i>) |

Table 2: Traffic matrix

| SPs | User Set | Traffic Rate | Example |
|-------------|---|--------------|---|
| 1 | Set I (#1 – #20) Set II (#21 – #26) Set III(#27– #29) Set IV(#30– #32) | 20 Mbps | 2 DVD ¹ quality video streams. |
| 2, 3, and 4 | Set II (#21 – #26) | 30 Mbps | 1 HDTV ² + 1 DVD |
| 5 | Set III(#27– #29) | 50 Mbps | 2 HDTV + 1 DVD |
| 6 | Set IV(#30– #32) | 50 Mbps | 2 HDTV + 1 DVD |

1 Average bandwidth for a MPEG-2 coded DVD video stream is 10 Mbps.
2 Average bandwidth for a compressed HDTV quality video stream is 20 Mbps

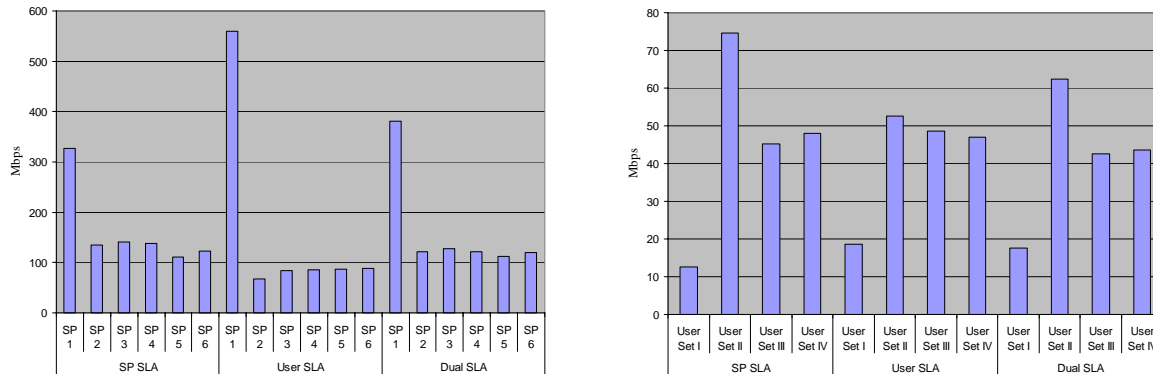


Fig. 3: Bandwidth assigned to (a) SPs (b) users for different SLAs

We observe that SP SLA ensures fairness in bandwidth distribution across SPs. However, User Set I receives an unfair share (close to 10 Mbps) of bandwidth in this scheme. The User SLA while granting good distribution of bandwidth amongst the users, leads to poor distribution amongst SPs (SPs 2...6 receive less than 100 Mbps while SP 1 receives close to 600 Mbps). The Dual SLA achieves good bandwidth distribution amongst both SPs and users. We observe that Dual SLA performs close to SP SLA for the SPs and close to User SLAs for the users, while meeting both *primary* and *secondary* SLA requirements.

4. Summary

In this paper, we argued that having SLAs in an access network will help in the deployment of QoS aware services for residential customers. We propose the concept of Dual SLAs and demonstrate them as a means of ensuring fairness to both SPs and users in an open access EPON network.

References:

- [1] Clause 64, 65, IEEE 802.3ah standard, approved June 24, 2004.
- [2] A. Banerjee and M. Sirbu, "Towards Technologically and Competitively Neutral Fiber to the Home (FTTH) Infrastructure", available at <http://100x100network.org/papers/banerjee-tprc2003.pdf>
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