Priority Mechanism for Multioperator FTTB Access Networks

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Abstract: - FTTB (Fiber To The Building) networks are a combination of copper wire and fiber optic telephone networks. This type of network incorporates the existing network of an established operator and legal or regulatory factors may require that an FTTB network be shared among various operators becoming a multioperator network. In this case, Quality of Service pose distinct problems from those of a typical unbundled or DSL (Digital Subscriber Line) network-linked loop.

In this paper, we address the problem of how quality of service provisioning that may be implemented maintaining all the quality-of-service procedures established by G.984 for GPON (Gigabit Passive Optical Network) and the standardized medium access control and bandwidth-management methods. Having analyzed all the mechanisms (standardized and otherwise) for guaranteeing quality of service in GPON, we identify two key aspects for managing a multioperator network: the establishment of priorities and the management of the medium-access method.

The proposed solution makes possible to guarantee Service Level Agreement for operators and maintain the proper quality of service for each operator, service and user.

Key-Words: -FTTB Multioperator, GPON, Triple Play Services, Quality of Service, Priorities.

1 Introduction

The multioperator concept refers to the capacity of an access network to simultaneously offer services from various telecommunications operators. The need for integrated (triple-play) delivery of voice, data and television services to end users demands ultra-high bandwidth and enhanced service quality; hence telecommunications operators are developing PON (Passive Optical Network) fiber optic access networks as FTTB (Fiber To The Building) networks [1].

In the case of new FTTH (Fiber to the Home) networks, regulatory authorities will probably not require telecommunications operators to share networks, so the concept of legally imposed multioperator service disappears. Nonetheless, in some areas, a lack of profitability for commercial telecommunications operators may lead official public entities to develop neutral multioperator networks to provide advanced services to areas that are not served due to the commercial development of the market. Both multioperator network architectures, FTTH and FTTB GPON (Gigabit Passive Optical Network) present new service quality problems that, in a pure DiffServ (Differentiation Services) environment, could be solved by careful assessment of access priorities and police mechanisms [2].

2 FTTB Multioperator networks

HFC (Hybrid Fiber Coaxial) network operators serve their end-users by using copper metal for telephone services, and coaxial cable for data and television services. Despite the fact that these network configurations are designed around fiber optic backbone loops and optical/electronic conversion HUBs at distances suitable for VDSL2 (Very high bit-rate Digital Subscriber Line) modems, they do not employ GPON and thus lie outside of the scope of this paper. Moreover, as these operators are not legally required to share their networks, multioperator functioning of HFC networks has not been pursued.

Incumbent telecommunications operators use copper wire to provide traditional voice, data and video services to their end-users. In the network architecture of traditional telephone network operators, there is a central hub from which metal wires radiate outwards in a star configuration to reach the end-home. Although the wires follow different paths of different lengths through feeder cables, distribution cables, and drop wires, there is physical continuity of the copper wires from the central hub to the end-user.

ADSL (Asymmetric Digital Subscriber Line) modems allow the integration of triple play services, while the multioperator effect that stems from legally imposed network sharing implies the full use of metal

wire by a determined operator, whether existing or entering, in order to prevent service quality problems in the access network. The quality of the service offered thus depends on the operator and on the continuity in its own backbone, rather than on the access network, which is unique and independent for each operator. Given that the last mile is the costliest for any change in access technology, incumbent operators have been replacing their distribution and feeder cables with fiber optic cables, while keeping their drop wires with GPON network configurations.
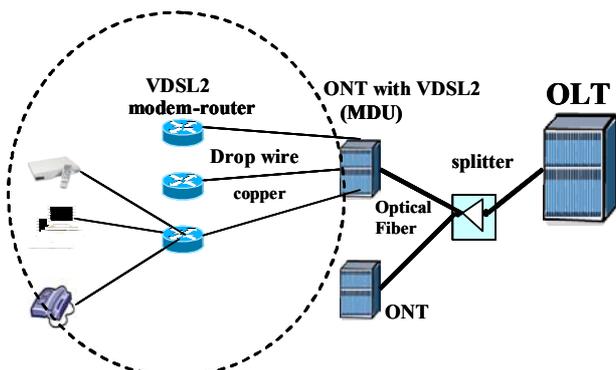

Fig.1. FTTB Architecture

This implies cutting the access network at the point where the beginning of the drop wire meets the distribution network, and installing VDSL2 modem cabinets that operate continuously through the drop wire until reaching the end-user. In Figure 1, the area surrounded by a dashed circle corresponds with the area that is maintained with metal wire. The distribution and feeder cable is substituted with the GPON network. The optical fiber extends all the way to the element known as the MDU (Multi Dwelling Unit). From a GPON perspective, the MDU can be considered as a single user. A maximum of 64 MDU can be used per GPON port, although each MDU can host as many VDSL2 modems as desired.Copper wires extend from the MDU to the users. The technology used in this section is VDSL2. End-users are equipped with a VDSL2 router that offers voice, data and television interfaces.From an operating perspective, the introduction of MDU in GPON networks effectively means that the GPON users have the same requirements as ONT (Optical Network Terminal) users, except that they must share the available bandwidth. If an ONT user has a maximum of 2.4 Gbps download and 1.25 Gbps upload for all triple play services, then the MDU users must share these theoretical maximum transfer speeds. Nevertheless, as VDSL2 technology allows for a maximum download speed of 50 Mbps, it does not present any practical limitations.

In a GPON-based FTTB network shared by various operators the bandwidth must be distributed among all the users with different Classes of Service. This generates distinct problems from those of shared ADSL networks, in which the operators that share the network do not share bandwidth. The network consists, see figure 2, of a generic router that provides access to the wired networks, data IP networks, interactive digital television networks, and analog and digital television broadcasting distribution networks of each operator that shares the network. The OLT executes the GEM (GPON Encapsulated Method) protocol and manages the quality of service offered by the network. The traffic that circulates through a GPON network is Ethernet traffic. This traffic is the payload of GEM, which contains all the necessary elements to define the Medium-Access Control [3]. The traffic flows are handled based on priorities which one identified by the Alloc-Id (Allocation Identification). The OLT manages the access and distributes priorities at the MAC (Medium Access Control) level using the GEM protocol. Between the router and the OLT there is a VLAN for each user/service in an ONT/MDU/VDSL2 Router [4]. In terms of types of traffic, different general circumstances may occur with triple-play (voice, data and TV) service. Different types of isolated or combined traffic can be created. We will consider their performance in terms of latency, data loss and throughput.
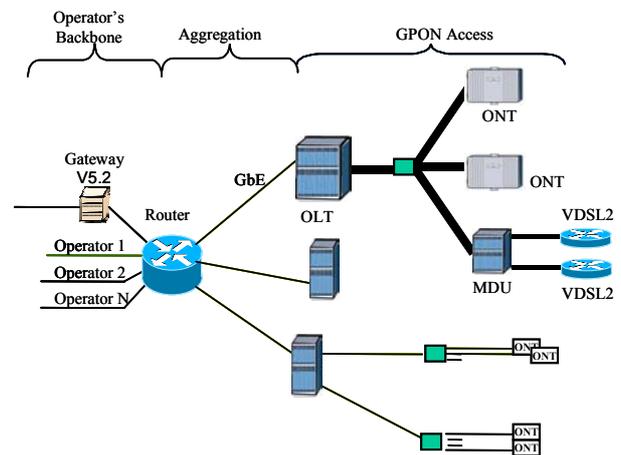

Fig. 2. FTTB Multioperator architecture

The definition of GPON does that, with a point-to-multipoint architecture, all the users who hang of a same optical fiber, receive a frame that contains the information of all the users with whom they share the fiber. Diverse mechanisms make that each user is only able to receive the information directed towards him [5].

3 FTTB Multioperator Quality of Service

In order to ensure that the traffic flows get the proper quality of service and to implement police functions, we must measure the availability of prioritization of streams in a triple-play environment.

Several quality-of-service parameters must be applied to quantify throughput and response times for different traffic combinations. Internet traffic is given the lowest priority, since data services are not drastically affected by packet delays. Video traffic has the next highest priority, since a minimum loss of video packets does not negatively affect the perceived quality, as long as the audio streaming track is not broken. Finally, voice over IP will have the highest priority, since voice services are very sensitive to latency and loss of packets.

GPON specifies five different types of traffic known as T-CONT. These definitions are related to throughput and delay. The DBA (Dynamic Bandwidth Algorithm) makes it possible for the MAC controller of the OLT to create an image of the queuing situation for each type of traffic in the whole GPON network, thus enabling an effective allocation of throughput and control of delay [7].

As GPON traffic is multiplexed, there are different possibilities to manage the traffic, because that each ONT can have several T-CONT, and each T-CONT can have several GEM Ports [8]. An identifier of VLAN (Virtual Local Area network) and 802.1p priority will be associated to each T-CONT port. Traffic in T-CONT is managed from the OLT making the bandwidth assignment to distribute available resources.

In a regular GPON network, quality of service is guaranteed for each service and end user [9]. Priorities are therefore set in accordance with this scheme and the management procedure does not consider any another options. In our case, however, where the FTTB/VDSL2 network is multioperator, it is necessary to maintain the QoS (Quality of Service) not only for each service and user but for operator too. There are two concepts that with one operator haven't importance, but with more than one operator it is necessary to analyze with more detail.

First, the prioritization criteria must take this fact into account. With more than one operator, incrementing granularity of priorities could be an increment of opportunities to achieve network access when congestion occurs. An end user may have more than one voice-over-IP line contracted through an operator. For data an operator may offer its clients a provide Committed Information Rate (CIR), as for video, operators can offer their clients simultaneous

television services with different channels or different video-on-demand sessions. This range of possibilities cannot be generalized by all operators that share a GPON. Each operator's range of possibilities will depend on its IP backbone and video-server capacity. Quality of service is allocated based on priority queuing and bandwidth allocation by user, not by operator, in accordance with GEM (GPON Encapsulated Mode) and using DBA (Dynamic Bandwidth Allocation) [9].

Second, each station will be able to transmit a flow according to the authorization from the OLT that allows it to do it. Permissions are based on the network load studies that generate a table of polling taking into account the contracted SLA (Service Level Agreement) and to the priority of the flow. In the case of multioperator, network fairness among operators must be guaranteed.

All operators must have the same opportunities in case of congestion. To do this, the table of polling must be adapted to this situation with a multioperator polling algorithm.

Once we have identified the key aspects witch differentiate the multioperator architecture the solution we propose for this problem is twofold: a new range of priorities and a new criterion to create the medium access table [10].

4 Proposal

First, in a single-operator GPON access network, the MAC controller in the OLT manages the various services set of by assigning different priorities. In a multioperator FTTB/VDSL2 network, because each operator offers its own services, we must make some changes to the GPON MAC controller.

We propose the following criteria for 802.1p priorities assignment. Each operator must be able to offer multiple voice channels, television channels and data channels (controlled by the respective police functions).

We propose modifying the number of priorities and a different type of priority should be considered for each service (table I). We consider allowing up to four services for TV because this is generally the maximum number of television sets per home, and maximum three lines for voice is considered sufficient usually.

For each ONT or VDSL2 router, each operator will define a certain priority for each service and will enter into an SLA (Service level Agreement) with the network. For instance, if a subscriber from ONT/VDSL2 has two voice channels, one may have priority 7 and the other may have priority 1, or both may have priority 4. Each operator chooses the

priorities of the services offered to its users and the level of QoS (Quality of service). All combinations of priorities can be used and the priority is based on the service, user and operator.

Voice	Television	Data
7	6	5
4	3	-
1	2	-
-	0	-

Table1. Service priorities assignment

We could analyze the amount of traffic blocked when using the simple priority assignment (one priority per service) and the proposed number of priorities. The improvement obtained in case of congestion using the proposed priorities model supposing that lines/channels more than one have low priority. The operators sacrifices second voice lines or second TV channels in front of the first. They must model their offer in function of the wished performance.

With this priorities scheme the wished improvement is achieved when congestion is produced and an operator/user/service is blocked. Figure 3 indicates this situation. A user not will be blocked when congestion appears if there are more than three priorities for all users. Point B indicates that the value A can improve if the priorities of the different services are using the proposed table and second lines for TV and voice have low priorities than the first, based on SLA contracted, and the difference between B and C and other values along the axis are if the second, third or fourth lines have low priorities than the first, or the second or the others.
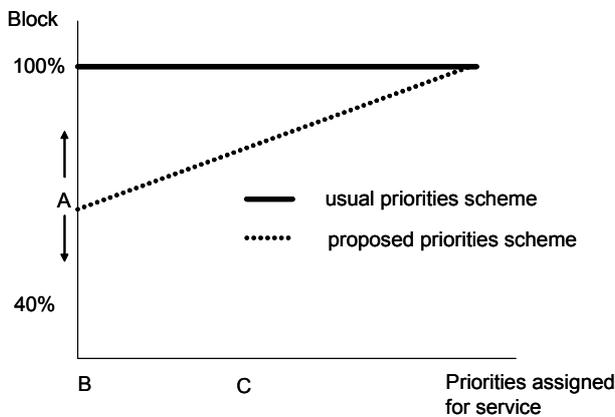

Fig.3. Improvement due new priorities scheme

The absolute value of A depends on the percentage of service lines (one, two, three or combinations) for total triple-play users and the percentage of every type of service (voice, TV and data). For instance that among all users they have 30 % with Voice, TV and data, and for voice service, 80% have one line, 19% have two lines and 1% have three lines.

Second, the activity of the centralized controlling polling table must be developed not only to maintain the quality-of-service parameters for each ONT, but also to satisfy the demands of the various operators that share the GPON network and MDU. In order to guarantee the SLA for each service and to maintain fairness among services and operators, polling slots must be assigned to each operator based on the distribution based on the number of users per operator. The polling must be defined not only to maintain the quality-of-service parameters for each ONT but also to satisfy the demands of the various operators that share the network.

We propose a polling cycle that takes into account the number of users per ONT and per operator. Therefore, access is distributed and slots are allocated based on the number of users per operator. The regular priority-based Dynamic Bandwidth Allocation (DBA) algorithms are applied along with round robin process.

We consider N operators sharing a GPON access network and each operator has TUSi users (one MDU can to have many users from different operators), then the total number of users

$$TUS_t = \sum_{i=1}^{N} TUS_i$$

For each polling cycle, each operator will have RRi slots,

$$RR_i = TUS_i \ / \ TUS_{min}$$

being TUSmin the lowest value among all operators. RRi is normalized so that it becomes an integer value. Distribution polls long the time will assure number of polls for operator after rounding operation. With this operation we assure that the polling cycle is the minimum value among the possible ones. For instance if we have two operators, one with 100 users and other with 50 users, the polling cycle could be 150 polls with 100 for operator one and 50 for operator two, or applying the result of our proposal with would obtain a polling cycle of 3, 2 for operator one and 1 for operator two. Now the problem is how the OLT can distribute these polls along the time maintaining the Quality of service for all operators and users using DBA.

In order to assign RRi to each operator and user by OLT using DBA we propose to adapt a well know

mechanism taken from the GCRA (Generic Cell Rate Algorithm) for control [11].

The total of polls per cycle is

$$T = \sum_{i=1}^{N} RR_i$$

If we consider SPR as the Sustainable Poll Rate, PPR as the Peak Poll Rate and MPB as the maximum number of consecutive polls, then τp is the number of polls at peak rate, τs is the number of polls at sustainable rate and τt is the number of polls among consecutive polls.

Then, for GCRA we have $SPR_i = 1/RR_i$, and $PPR_i = 1/$minimum distance between polls. Considering $\tau_p = 1/PPR$, $\tau_s = 1/SPR$, the Maximum Poll Burst (MPB) in T will be

$$MPB = \lfloor 1 + \tau_t / (\tau_s + \tau_p) \rfloor .$$

Given the MPB, τp and τ_s, then τ_t can be any value in the half-closed interval

$$[(MPB-1)(\tau_s - \tau_p), MPB(\tau_s - \tau_p))$$

and we recommend to use the minimum value

$$\tau_t = (MPB - 1)(\tau_s - \tau_p)$$

being $\tau_s + \tau_p$ the minimum separation allowed between MPB.
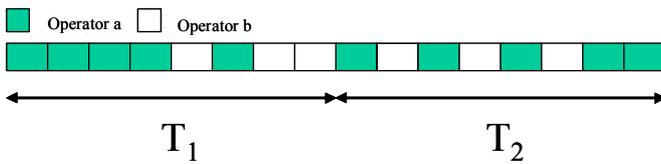

Fig.4. Polling distribution

An example for two operators with RRa = 5 and RRb = 3 (operator a has 100 users and operator b has 60 users), with MPBa = 4, MPBb = 2, PPRa = PPRb = 1/1, SPRa = 1/5 and SPRb = 1/3 is indicated in figure 4. In this case $\tau_t = 6$ and $\tau_t = 4$ respectively.

This simple modification of the polling cycle guarantees both quality of service and fairness independently from operator in the worst case. We can see that, for quality of service among operators, is better in case of congestion the distribution of polls indicated in T2. The risk that an operator could be affected by congestion is lower.

Using the adjusted polling table in multioperator FTTB network there is a better distribution for band assignment related with use the network by several operators. Neutral operator must quantify MPB and PPR in SLA for each operator. These parameters are correlated, and high values for one improve this operator and deteriorate the others operators. For better result we recommend use the more distributed poll for operator in T maintaining the parameters SPR, PPR and MPB with values in margins calculated per operator.

5 Conclusions

When a GPON network becomes in congestion, priorities based control systems are activated for service and user. With many operators, is possible to distribute the risk per operator increasing the number of priorities and distributing medium access poll between operators as much as possible. Control procedure mechanism that improves the results versus congestion has been presented. Needed parameters they will be negotiated in traffic contract per operator and its implementation is easy with knew mechanisms.

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