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QoS ASSURED DYNAMIC BANDWIDTH ALLOCATION IN EPON-LTE NETWORKS

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ABSTRACT

Ensuring stringent Quality of Service (QoS) requirements is a critical issue in determining the performance of the network. Added to that, when the network happen to be converged Ethernet Passive Optical Network (EPON) and Long Term Evolution (LTE) which is essential for today's bandwidth-intensive customer needs, it is still more critical. Hence, allocation of resources to the end-points is the crucial process in such a converged network. This paper reports a new scheme for allocating time-slots to the end user services in converged EPON and LTE networks. And it is enhanced to support QoS by establishing a mapping mechanism between the LTE bearers and EPON queues. Simulation results reveal that throughput and other QoS services, such as jitter, delay excel in the employed scheme than the traditional one.

Keywords: *LTE, EPON, Dynamic Bandwidth Allocation, QoS provisioning*

1. INTRODUCTION

In place of traditional voice services, demand for bandwidth-intensive services like music and video downloads, streaming services, web surfing, IPTV are gaining momentum. This in turn challenges service providers globally to increase the user bandwidth beyond voice and basic data services for which they have to introduce dramatic changes in the wired and wireless networking infrastructures. Also recent technological developments in wired and wireless networks promise seamless access of unlimited bandwidth to consumers and business users.

On the wireless side, the industry faces a steep growth of subscribers and high-speed data services. This has accelerated the development and deployment of fourth generation (4G) wireless networks, such as LTE that is capable of delivering speeds better than the current fixed-line broadband access systems. The backhauling infrastructure based on microwave links for traffic from a base station to a central office will not be sufficient for high data rates [1]. On the wired network part, copper access networks are no longer able to meet the ever-growing consumer demand for bandwidth. Latest advances in PON technology have propelled it to be a possible successor to the current copper based solutions. Also next generation optical networks, like PONs provide an alternative solution for high capacity backhauling links [2].

A convergence between the two, EPON and LTE is essential in the evolution of new generation networks. A major challenge in such a process is the selection of the right bandwidth allocation algorithm since it is exclusively responsible for the allocation of resources in the system. Also, in such converged scenarios an effective QoS mapping mechanism would be required between optical and wireless queues in order to avoid performance degradation of both types of users. To that extent, this paper describes a new novel dynamic bandwidth allocation algorithm for allocating bandwidth to ONUs and algorithm to accommodate QoS mapping.

The research community has unfolded different aspects of the Dynamic Bandwidth Allocation (DBA) process and here are a few worth mentioning. Interleaved Polling with Adaptive Cycle Time (IPACT) [3] is one of the earliest and most effective attempts in providing an improved DBA algorithm. In IPACT, the OLT polls each ONU in a round-robin fashion and dynamically assigns bandwidth to them. In order to better utilize the available bandwidth, the next ONU is polled even before the current ONU has finished transmission. OLT grants the ONU's requested bandwidth but does not exceed a maximum

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boundary and hence adopts a limited allocation approach. Accordingly, IPACT utilizes bandwidth more efficiently than static DBA PONs, and is used to develop other EPON DBA algorithms. [4] details other DBA algorithms based on IPACT, that are two-layer bandwidth allocation, guaranteed minimum bandwidth and Intra-ONU bandwidth allocation schemes. Against the fact that different data rates are supported by both PON and SPs and different service levels are assigned according to customers' requirements, all the above approaches assign a single service level and same aggregate data rates to the ONUs.

Authors in [5] support QoS by providing the high and low priority services with fixed and dynamic bandwidth allocation respectively. High priority services are guaranteed with a fixed bandwidth and the fairness of sharing the bandwidth dynamically is achieved with a weight-age factor for each ONU based on its accumulated low priority data. Nevertheless, this attempt does not guarantee a minimum bandwidth for low priority services. A new view of DBA is presented in [6], where the different service classes are allocated with bandwidth before distributing among the ONUs. By this, the class level QoS is prioritized over ONU level bandwidth allocation. However, practically service providers would like to prioritize ONU-level bandwidth guarantee. [7] focuses on a single-user-per-ONU scenario, wherein a LLID is assigned to per-queue in an ONU and OLT allocates bandwidth on per-queue and not per-ONU basis. This approach takes the OLT to a higher level of DBA process. The DBA scheme proposed in [8] attempts to provide a predictable average packet delay and an improved delay jitter but only for the expedited forwarding traffic.

From the SP's perspective, fairness is determined by the SLA between the OLT and the ONUs which means bandwidth allocated to a ONU in a cycle should satisfy the terms of SLA even before its request for the current cycle. This will ensure that any ONU is not affected by another ONU overloading the network. Most of the earlier works enforce the fairness of bandwidth sharing based on the ONU's current request. Hence an attempt is made in this research work to enforce QoS in the EPON-LTE convergence and also fine tune the DBA process in a different perspective to maximize bandwidth utilization and minimize packet delay, which are the objectives of a good DBA algorithm. Though EPON and LTE represent fixed PON and 4G mobile access technologies in our work, the proposed algorithm is also applicable to other PON and 4G access networks such as GPON and WiMAX.

The technical discussion in the upcoming sections is organized as follows:

- Section 2 describes the proposed algorithm for EPON-LTE integration in detail
- Section 3 narrates the mapping between EPON priority classes and LTE services to ensure QoS for LTE for backhauling
- Simulation Model used for evaluating the proposal is described in Section 4.
- Section 5 briefs the overall results of evaluation followed by discussion and scope of further research.

2. DBA ALGORITHM FOR EPON-LTE INTEGRATION

The proposed work is detailed in this section. As defined in the 802.3ah standard [9], the ONU reports the OLT of its bandwidth requirement through the REPORT packets for which the OLT grants time slots by means of GATE packets to each ONU for its transmission. In our proposed work, during each cycle the OLT initially dynamically assigns to each ONU a guaranteed minimum bandwidth from the available network bandwidth that meets their SLA (SLA is the contractual agreement on the service-level to be provided to a customer by a service provider). The OLT is designed to be configured with the SLA values of the ONUs. Thereafter, the OLT apportions the left-out unused bandwidth to the requesting ONUs based on the priority of their request. Thus the OLT is capable of guaranteeing the minimum bandwidth and distribute the unused bandwidth among the ONUs to comply with subscriber promise in the event of varying network capacity. Also, fairness is maintained in the system by serving the ONUs in a round-robin fashion starting from the last served ONU in the previous cycle. The algorithm is explained in detail in the following sections.

ONU estimates its bandwidth requirement for the current cycle which is the queue length of the data to be transmitted along with the predictive value of the arriving data in the waiting time. Total bandwidth requested by the ONU for servicing all its requests for the current cycle is calculated and the ONU informs the OLT of its requirement by

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framing the REPORT message with the details and sends it to OLT.

OLT on receiving the REPORT message from a ONU, processes the message and calculates the ONU's bandwidth requirement. The OLT then based on the bandwidth allocation algorithm it follows, grants certain bandwidth to the ONU. In the proposed algorithm, the OLT on receiving a request from the ONU assigns the bandwidth in two levels. In the first level, the OLT grants either its SLA bandwidth or its requested bandwidth based on whether the request is higher or lower than the SLA value. OLT grants the above bandwidth immediately to the ONU without waiting for request messages from rest of the active ONUs. For ONUs with request higher than its SLA agreement, the first round of GATE message with SLA bandwidth allocation does not generate a REPORT message in response by resetting the 'Force Report' flag in the GATE message. Whereas, for ONUs with request lower than or equal to its SLA agreement, a single GATE message is sent and the allocation meets its request. This GATE message generates a REPORT message in response to continue with the transmission process for the next cycle.

In order to dynamically assign more bandwidth to the requesting ONUs, the OLT does the second level of bandwidth allocation if available. During the second level of allocation, the OLT sends another GATE message to all the high bandwidth requesting ONUs with its excess request of bandwidth if available. This allocation is done in a round-robin fashion starting from the last ONU to the first in the high requesting ONUs list and also high priority requirements of the ONUs are served before any of the low priority requirements are processed. Thus all high bandwidth request ONUs are given an opportunity to grab more bandwidth if available. The last served ONU is remembered and in the next cycle the round-robin process starts from the previous ONU. The second GATE message unlike the first informs the ONU to respond back with a REPORT message to continue with the transmission process for the next cycle.

A GATE message with zero bandwidth is sent to each high requesting ONU if no bandwidth is left for the second level, since a REPORT message has to be generated from these ONUs in order to continue with the transmission process for the next cycle and the first round of GATE messages wouldn't have generated REPORT messages.

3. QoS MAPPING FOR LTE BACKHAULING

To further improve the algorithm, QoS guaranteeing is done in the converged network by employing a mapping mechanism between the EPON priority queues and the bearer-based LTE flows.

EPON supports eight priority levels with the QoS for the service represented by the numbered priority queue in the 802.1P nomenclature. QoS in LTE is determined by QoS Class Identifier (QCI), Allocation and Retention Policy. The 9 QCI values define eight characteristics for IP packets ranging from VOIP call to email and chat. The mapping between the EPON priority queue and LTE flows provides equivalent QoS levels at both ends as detailed in Table 1.

Table 1: EPON - LTE QoS mapping mechanism

Priority	LTE services	EPON traffic types
0	IMS Signaling	Background
1	VOIP Call	Best Effort
2	Video Call	Excellent Effort
3	Online Gaming	Critical applications
4	Video Streaming	Video
5	Video (buffered streaming)	Voice
6	Voice, video, interactive gaming	Internetwork Control
7	TCP-based (e.g. WWW, e-mail), FTP, P2P, etc.,	Network Control

4. SIMULATION MODEL

The performance of the proposed work is evaluated using OPNET simulator for the converged LTE-EPON architecture. A EPON network is devised with a single OLT and 16 ONUs with varying SLAs to represent different service levels. To support the LTE network, a 1Gbps EPON network is chosen as the backbone network with a 2ms maximum cycle period and 1µs guard to establish data transfer between the OLT and ONUs. All type of service requests are loaded to the LTE network and starts loading after 100ms from the start. Since it is important to evaluate a system for time critical applications, the system is loaded with delay sensitive VOIP call requests. The simulation model

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is evaluated for the most critical uplink part although the framework supports both uplink and downlink transmissions; hence, all connections are in the uplink direction, originating from each user equipment.

5. RESULTS AND DISCUSSIONS

This section discusses the results of the execution of the proposed framework.

The throughput for the conventional scheme and the proposed scheme is measured under the same setup and plotted against time. Figure 1 clearly illustrates that the performance of the proposed DBA algorithm is well ahead of the conventional scheme in terms of throughput. On-the–fly assignments of bandwidth to the ONUs without waiting for requests from all the ONUs proves to be a positive step towards the betterment of the DBA process and has helped the system to improve its performance as can be seen from the plot. On-the-fly grants reduces the idle time in the OLT involved for the collection of report messages from all the ONUs and processing all of them to determine the bandwidth to be allotted to each ONU and then assigning each ONU with its bandwidth allocation.

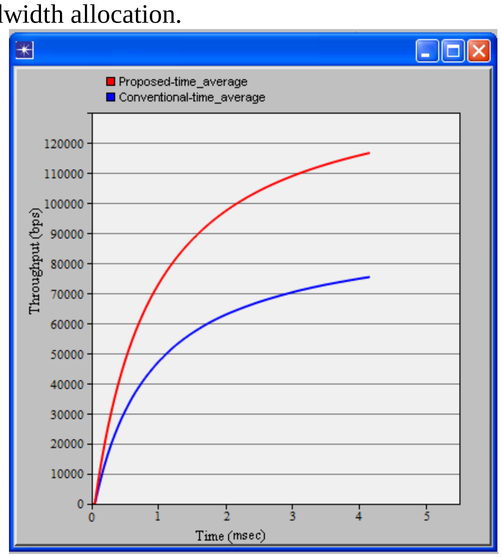

Figure 1: System Throughput

The framework improves the DBA process by enhancing QoS by favouring high priority requirements than low priority requirements. Also, fairness is maintained by assigning all ONUs with equal weight which is enforced by assigning excess bandwidth to high requesting ONUs in a round-robin fashion. The shortest path ONU will always be the first in the list and the process may end up favouring it in each cycle. In order to avoid it, the last served ONU is remembered and in the next cycle the serving starts from next ONU to the last served ONU. To enhance fairness, the second level of bandwidth allocation starts from the last ONU in the high requesting ONUs list and moves forward in the list.

Next, QCI packet delay characteristics are studied for mapping and non-mapping EPON-LTE convergence with respect to increasing user equipment (UE) in the cell. Also, the algorithm improves QoS by serving high priority requirements with more bandwidth than low priority requirements when the bandwidth is available. When the QoS mapping is employed, the high priority LTE service exhibit decreased packet delay compared to non-mapping as can be seen from the figure 2.

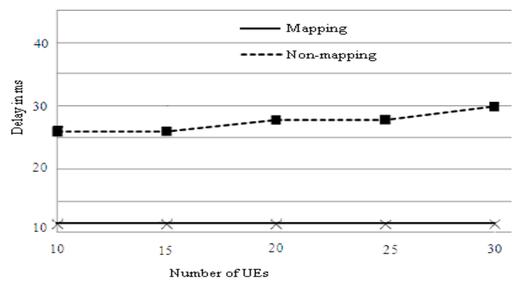

Figure 2: Delay For Mapping And Non-mapping Mechanism

Even though not being the only metric in evaluating the performance of any network system, throughput is the most important metric and other QoS parameters should not be compromised for an improvement in the throughput. Hence it should be verified whether the improvement in the throughput of voice calls is not achieved at the cost of the other voice performance metrics, delay and jitter. The proposed schema reduces the voice end-to-end packet delay depicted in figure 3 and also maintains the jitter which is depicted in figure 4.

Similar to voice metrics, it is important to verify the video performance metrics. However, figure 5 illustrates that the packet end-to-end delay has reduced for the video packets also and figure 6 illustrates that the video traffic received has improved for the proposed algorithm.

As can be seen from the results obtained, the achieved performance justifies the objective of the research work: that is bandwidth allocated to a ONU in a cycle should satisfy the terms of SLA in the EPON-LTE converged network. Also the results emphasis that the research attempt enforces QoS in such a convergence, and also fine tunes the DBA process to maximize bandwidth utilization

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and minimize packet delay, which are the objectives of a good DBA algorithm. These are the achievements of the proposed work compared to the earlier attempts by various research works discussed in the literature review [3], [5], [6], [8].

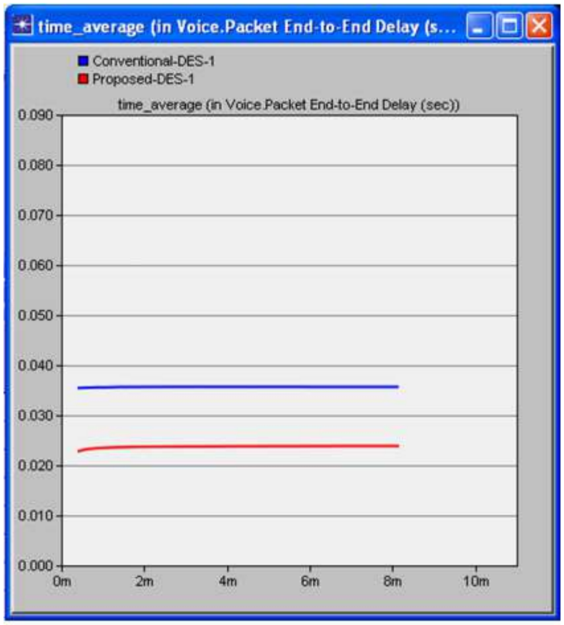

Figure 3: Comparison Of Voice Packet End-to-End Delay In Conventional And Proposed Scheme

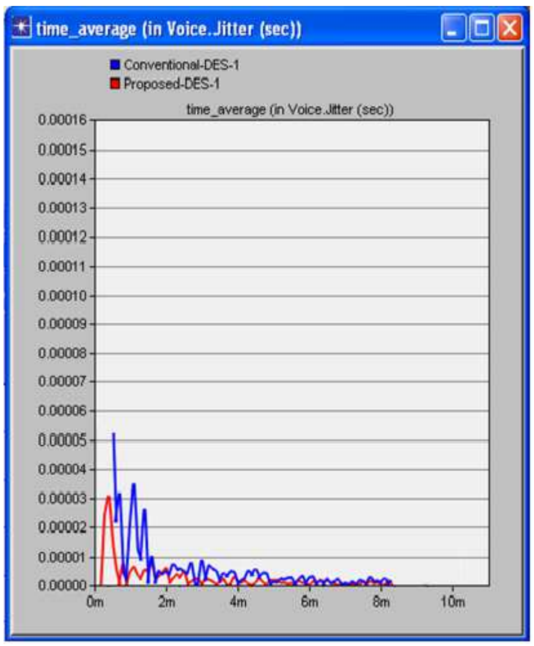

Figure 4: Comparison Of Voice Packet Jitter In Conventional And Proposed Scheme

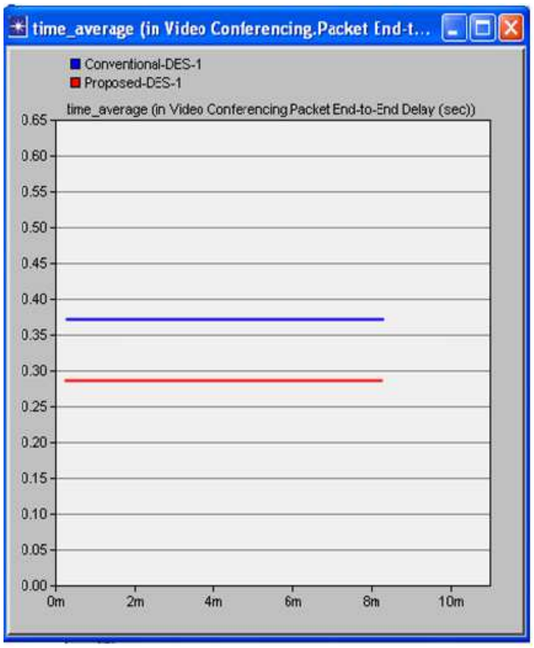

Figure 5: Comparison Of Video Packet End-to-End Delay And Jitter In Conventional And Proposed Scheme

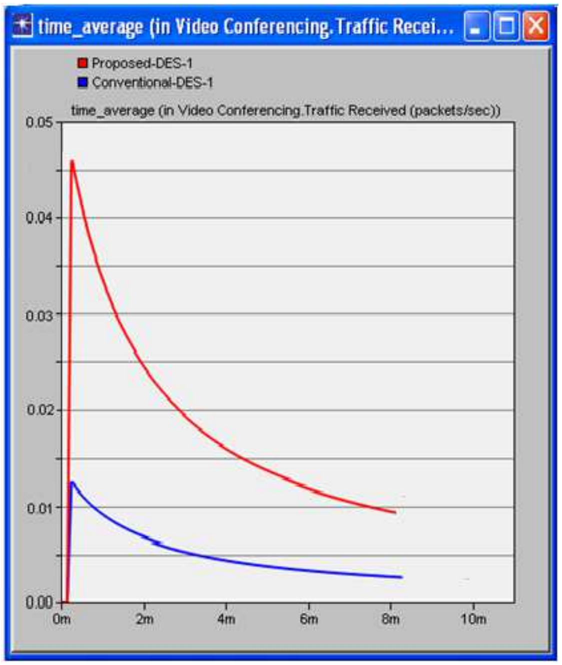

Figure 6: Comparison Of Video Packet Traffic Received In Conventional And Proposed Scheme

6. SUMMARY AND CONCLUDING REMARKS

The performance of the network system is largely determined by the efficiency of the chosen

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DBA algorithm. Hence in this paper, a DBA scheme that meets the customer SLA, such as bandwidth, delay, and jitter is proposed and verified using simulations. The paper also addresses another key factor critical in determining the performance of EPON-LTE convergence which is QoS mapping between the user equipments and ONUs. The scenarios and performance evaluation discussed in this paper are based on EPON-LTE network. The results obtained prove that the performance of the network has significantly increased along with ensuring QoS in the network. Also, the system proves to be an efficient high capacity backhaul network with the fact that the measured delays for all services are well within the limits defined by the LTE standard.

Still, there exists a limitation in the algorithm that it only frames a model for bandwidth allocation between OLT and ONUs, but does not deal with the resource allocation among the services in a ONU. Therefore, the future research work can be carried out by extending the algorithm to address this limitation.

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