Quality of Service (QoS) Analysis for Decentralized Passive Optical Network (PON) Intelligent Algorithm

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Abstract--- Bandwidth controlling especially Decentralized Dynamic bandwidth allocation (DBA) is one of the essential issues in design and implementing PON system that has been studied by many researches. This paper introduces the QoS analysis for the decentralized DBA concepts on EPONs based on intelligent agent protocol and its intelligent bandwidth allocation. The approaches aim to distribute the bandwidth controlling from only OLT to inside each ONU in an intelligent way. The proposed decentralized traffic controllers using IDDBA based on intelligent agent's in EPON could enhance the network performance specification as it will be proved in this paper by breaking down the complexity of upstream congestion problems in to simpler problems handled by distributing the simulation design system to improve the QoS.

Key-Words-- QoS, Bandwidth allocation, EPON, intelligent algorithms, wasted bandwidth

I. INTRODUCTION

The Internet is changing from a purely data network, where it was designed based on the best effort, and able to cater simple classical applications like e-mail, file transfer and remote access enhanced to a network that is capable of carrying various types of traffic with different requirements such as; VoIP, video conferencing and video broadcasting.

The new generation of users demands QoS guarantees for the emergence new applications, these applications range from voice and video streaming to enhanced data transfers adding the on-going evolution of the traffic profiles in the Internet. This huge amount of applications cause the needs to differentiate the traffic so that each type can be treated differently based on their inherent requirements, and pressing the need for realizing enhanced traffic control in the Internet for these emerging demands. This can be done by studying the performance assurance and service differentiation, or together they are referred as the QoS.

QoS is the ability to provide different priority to different applications, users, or data flows, or to guarantee a certain level of performance to a data flow. For example, fairness, bandwidth utilization, packet delay and wasted bandwidth.

Decentralized mechanism has been studied widely on many different applications that are based on intelligent agents [1], [2]. The idea behind any multi-agent system is to break down a complex problem handled by a single entity or a centralized system into smaller simpler problems handled by several entities or a distributed system. Intelligent decentralized scheme with Intelligent Decentralized DBA algorithm (IDDBA) that uses agent technology is introduced, which is critical to many technological domains such as traffic managements and bandwidth allocation for next generation access network EPON.

By using decentralized bandwidth allocation, complicated QoS metrics (from end user's point of view) can be communicated in a simplified manner. Service provider and network provider agents can then negotiate with users' agents in order to meet the required service [3].

In this paper, the IDDBA algorithm mechanism with agents discussed in section 2, while section 3 design parameters for the simulation study, section 4 sustains the performance analysis for decentralized mechanism, and section 5 conclude the paper.

II. Intelligent Decentralized DBA with Agents

IDDBA is a decentralized DBA algorithm using Artificial Intelligence (AI) based on a direct communication protocol using software intelligent agents. The Intelligent decentralized scheme possesses the additional flexibility of modifying the bandwidth allocated amount and sequence of ONUs transmission in line with the ONUs traffic demands, priority, and the extra bandwidth available.

ONUs first request their bandwidth collected from all users. Then, all agents inside ONUs will get a copy from the information and save it inside a look-up table. Once, the agents have communicated, the IDDBA will run simultaneously and granting the same result with bandwidth allotment for each ONU. Hence the data will be sent accordingly at the specific time assigned by the IDDBA at each ONU without any collision.

Belief Desire Intention (BDI) agents are able to balance the time spent on deliberating about plans based on the beliefs (choosing what to do) and executing those beliefs plans to match the desires (doing it). A third activity, is updating the state of each agent based on the chosen plan [4].

A. Beliefs represent the informational state of the agent inside the OLT and the ONUs, in other words its beliefs about the EPON environment (including itself at (OLT side) and other agents at (ONUs side). Beliefs can also include inference rules, allowing forward chaining to lead to new beliefs. Using the term belief rather than knowledge recognizes that what an agent believes may not necessarily be true (and in fact may change in the future).

B. Desires represent the motivational state of the agent. They represent objectives or ideal situations that the agent would like to accomplish or bring about to satisfy the bandwidth requirement of all ONUs.

C. Intentions represent the deliberative state of the agent – what the agent has chosen to do for the bandwidth allocation eg. Which ONU will get the excess bandwidth and how much, it will get. Intentions are desires to which the agent has to some extent committed. In implemented systems, this means the agent has begun executing a plan.

III. Design Parameters

A simulation study was conducted to illustrate the performance of the IDDBA with intelligent decentralized controller supported by intelligent agents compared to existing DBAs. The simulation parameters are shown in Table 1 and with the following traffic profiles.

Table 1 Simulation parameters

Parameter Symbol	**Description**	**value**
N	Number of ONUs	8 ONUS
B_{total}	EPON line rate	1 Gbps
T_{max}	Maximum cycle time	5 ms
S_{voice}	SLA Limitation for voice	20% total allocated bandwidth
S_{video}	SLA Limitation for video	40% total allocated bandwidth
S_{data}	SLA Limitation for data	40% total allocated bandwidth
Q	Buffer size	10 Mbytes
D	Diffserv priority queues	3
R_u	Line rate of user-to-ONU link	100 Mbps
T_g	Guard time	1μs
B_{min}	Minimum Bandwidth can be allocated to each ONU	62.5Mbps

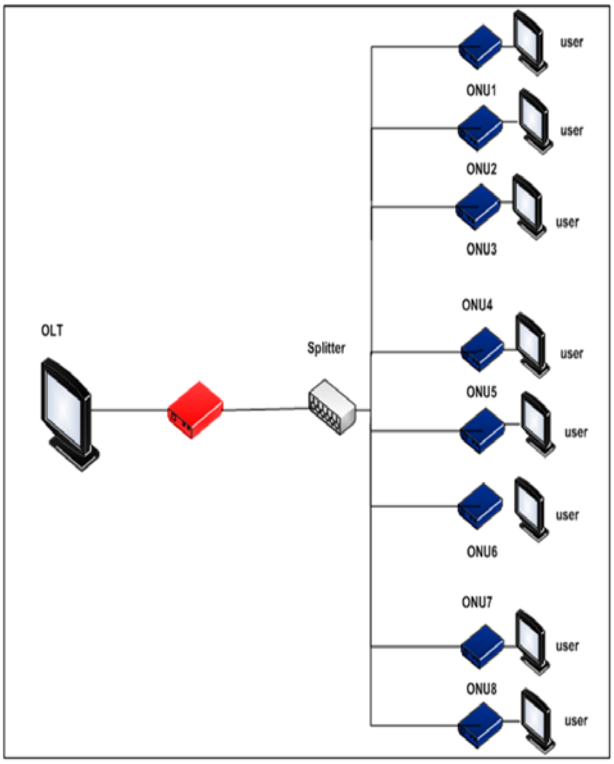

Fig. 1 EPON simulation network

IV. Performance Parameters

A comparison study of IDDBA is made with existing intelligent hierarchical algorithms for upstream transmission, referred as Intelligent Fuzzy Logic DBA (IFLDBA)[5] and Efficient Decentralized DBA (EDDBA) [6], and centralized DBA named Interleaved Polling with Adaptive Cycle Time (IPACT) [7]. The reason for comparing with IFLDBA is because of using the artificial intelligence especially (fuzzy logic) and with IPACT because it is centralized.

For the comparison, three types of priorities are used with the same requested bandwidth for all three types of traffic in IDDBA, EDDBA, IFLDBA and IPACT algorithms. The traffic load is a gain varied for the seven traffic load conditions and presented here the four heavy load cases. A simulation study was done to evaluate fairness, bandwidth utilization, delay, wasted bandwidth and improved percentage delay for the algorithms. All the design parameters that have been used in the simulation are the same.

The performance parameters show how good the output of the system will be. The parameters used to characterize the performance and qualities of the proposed algorithms are:

Fairness is a parameter that tells whether the bandwidth is equally shared within each ONUs or not. The closer the fairness index to 1, the better performance.

In Figure 2 the fairness index of IDDBA maintains around 0.89 to 0.98 from 0.1 to 1.1 Gbps. EDDBA has a less performance with around 0.85. While, IFLDBA fairness is 0.82 at full load and IPACT performance is 0.78 at high loads. Overall, Figure 2 improves that QoS is supported in IDDBA, where every ONU gets a fair share of the bandwidth according to the priority.

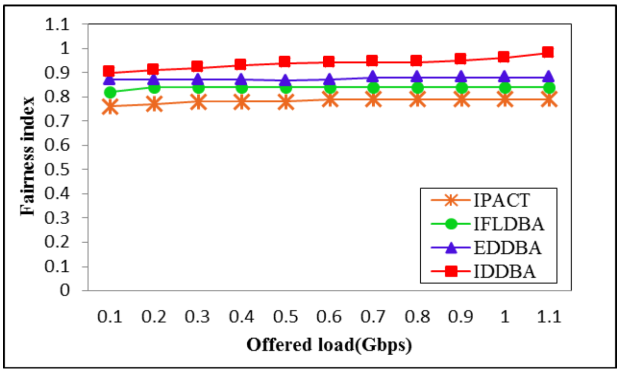

Fig.2 Fairness index versus offered load for IDDBA, EDDBA, IFLDBA, and IPACT

• The bandwidth utilization is the percentage of the bandwidth delivered successfully to the ONU from the OLT during specific time. It is very important to utilize the bandwidth enhanced in order to get better performance of the EPON [8].

All three algorithms show the same performance in Figure 3 for offered load 0 Gbps to 0.3 Gbps where at 0.3 Gbps offered load, the bandwidth utilization is 40%. After that, IDDBA utilizes the most bandwidth, reaches 92% at full load followed by 80% for EDDBA, 65% for IFLDBA and 57% for IPACT.

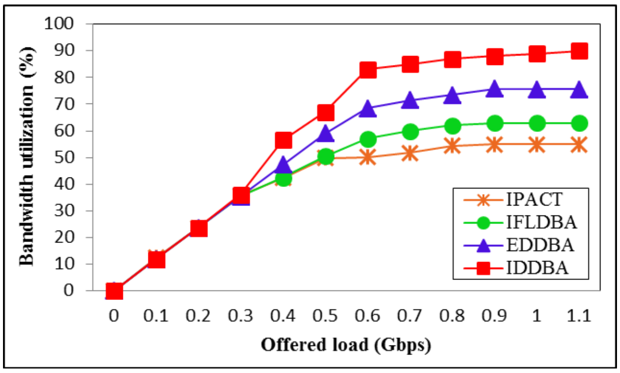

Fig. 3 Bandwidth utilization index versus offered load for IDDBA, EDDBA, IFLDBA, and IPACT

• The delay is the parameter that measures the latency, which can be happened between the beginning of the transmission of the first byte and the end of reception of the last byte.

For Figure 4, where the three algorithms have the same performance up until 0.3Gbps. After this, IDDBA delay is 0.001s, EDDBA delay is 0.002s, IFLDBA delay is 0.0019s and IPACT delay is 0.003s.

The video delay in Figure 5, IPACT delay is the higher with 0.05s, followed by IFLDBA and EDDBA with a delay 0.04s and 0.038s respectively. However, the delay for IDDBA is the lowest with a 0.025s delay.

The data delay in Figure 6. As shown in Figure 7.d, at light load from 0.1 until 0.3 Gbps offered load all algorithms give the same amount of delay 0.0 s. Beyond 0.4Gbps, IDDBA delay is 0.004s, EDDBA delay is 0.005s, IFLDBA delay is 0.006s, and IPACT delay is 0.004s. As expected, the delay for voice, video and delay have been reduced for the intelligent decentralized algorithm since the Agents inside each ONUs will send their reports once the packets arrived, and then the Facilator agent inside the OLT will get all the information in polling table and immediately broadcast the queuing state to the entire ONUs. Overall, IDDBA algorithm reduced the delay for the three services when applied for real time traffic.

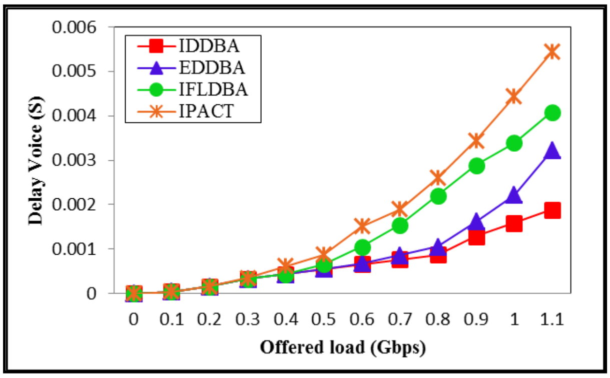

Fig. 4 Delay for voice versus offered load for IDDBA, EDDBA, IFLDBA, and IPACT

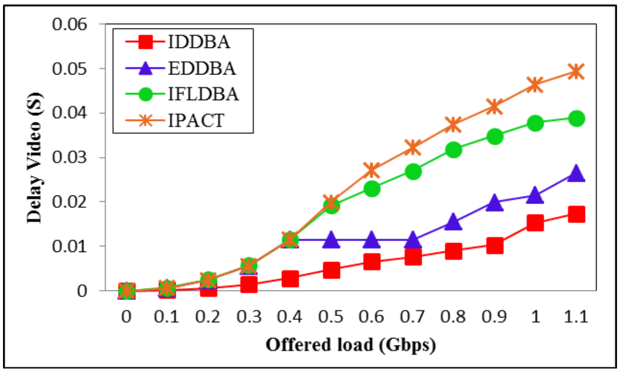

Fig. 5 Delay for video versus offered load for IDDBA, EDDBA, IFLDBA, and IPACT

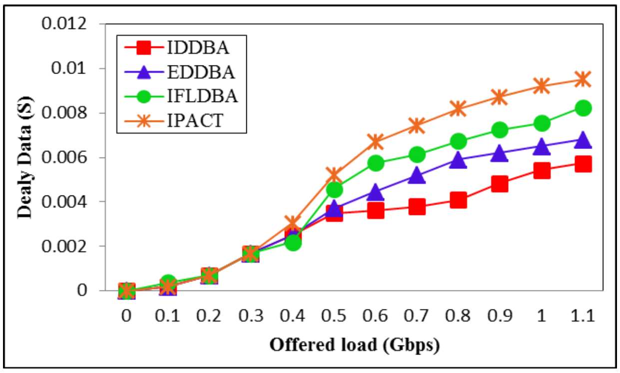

Fig. 6 Delay for data versus offered load for IDDBA, EDDBA, IFLDBA, and IPACT

• The wasted bandwidth is the parameter that calculates the excess bandwidth allocated to the ONUs, but the ONU does not need it.

Figure 7 shows a better performance for IDDBA in terms of wasted bandwidth compare to the existing EDDBA, IFLDBA and IPACT DBA. The highest value is 30 Mbps for IPACT, 22Mbps for EDDBA and IFLDBA compared to 10 Mbps only for IDDBA algorithm.

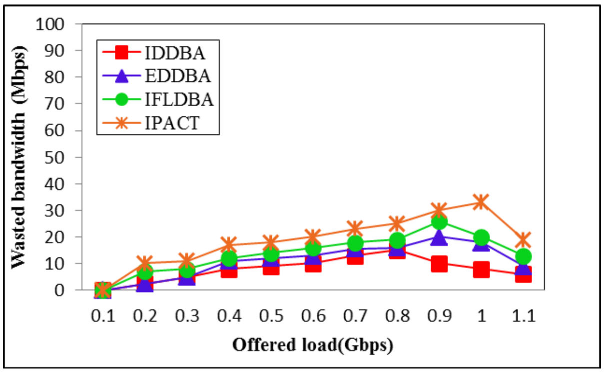

Fig. 7 Wasted bandwidth versus offered load for IDDBA, EDDBA, IFLDBA, and IPACT

V. CONCLUSION

This paper describes the QoS performance for the decentralized IDDBA algorithm in comparison to existing algorithms.

The algorithm support QoS and ensures inter and intra–ONU allocation algorithm independently at the ONU's side, supports triple play classes and improve bandwidth efficiency by allowing the ONUs to share the uplink bandwidth according to their bandwidth demands for different traffic priority classes autonomously where voice traffic is granted as the highest priority in the entire EPON system followed by video and data traffic.

It uses decentralized scheduling to make the allocation of the bandwidth more accurate and to make the algorithm's processing delay lower. It also utilizes excessive bandwidth more fairly as each ONU has the overall view of the queues supported by direct communication between ONUs.

Overall, the IDDBA mechanism introduces a unique identical DBA algorithm running simultaneously at the same time in each ONU. It is asynchronous, scalable, dynamic and added more flexible and reliable handling for data, voice, and video.

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