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'TD-Sense Algorithm'-A Novel Approach to Improve Network Performance for 1G-EPON

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Abstract – This paper proposes a novel 'TD-sense algorithm' for improve the network performance and compares it with a standard DBA_GATED algorithm. The algorithm is implemented by emulating an access network with the use of two 1G transceivers for 1G EPON. The algorithm is tested for Triple Play services that include simulated voice, video and data packets. The algorithm is found to maintain a better tradeoff between throughput and delay, than the existing DBA_GATED algorithm.

Index Terms – OLT, ONU, Triple Play, Average Delay, Throughput, REGISTER, QOS, MTU

1. INTRODUCTION

Passive optical networks (PON) were developed to satisfy the demands of high bandwidth and larger coverage needs of future access networks [1]. A Passive Optical Network is a point-to-multipoint network that has no active elements in the path of the signals from source to destination [2]. The emergence of PON has reduced the cost to transmit data from Optical Line Terminal (OLT) which is located at the central office (CO) to Optical Network Unit (ONU) that provides broadband internet access to the subscribers. Ethernet PON (EPON), designated as IEEE 802.3ah, carries data traffic encapsulated in Ethernet frames over PON based network. 1G – EPON supports transmission and reception of data packets at the rate of 1 gigabits/second. The OLT uses Dynamic Bandwidth Allocation (DBA) to allocate bandwidth dynamically to the ONUs depending on the current traffic load at the ONU. We propose a novel algorithm for bandwidth allocation named 'TD (Throughput Delay)-Sense algorithm' wherein the OLT classifies the data traffic into two different types and allocate the bandwidth according to priority. This is implemented by using two 1G transceiver cards fixed to two computers connected by fiber optic cable, one acting as OLT and the other containing multiple ONUs. We have compared the performance of the novel algorithm with an existing algorithm.

2. DBA_GATED ALGORITHM

PON architecture comprises of an OLT located at a Central Office, connected to various ONUs through Optical Splitter. OLT acts as an interface between the core and the access network. The downstream channel from the OLT to the ONUs employs a single transmitter at the central office and the upstream channel is shared among the various ONUs [1]. The OLT broadcasts the traffic in the downstream channel to all ONUs. DBA algorithm is used as medium access control mechanism which is employed to achieve the best possible usage of the bandwidth for the upstream channel usage from the ONU to the OLT. Each ONU calculates its bandwidth requirement as per its buffer contents. Then it sends a request frame to the OLT with the desired transmission window request. The OLT receives multiple requests from different ONUs at the same time. It then uses DBA algorithms to calculate the amount of bandwidth to be allotted to each ONU and sends the grants to each ONU, after which each ONU transmits in its own time window.

Multi point control protocol (MPCP) controls the upstream multiple access to allow efficient transmission of data. Five control messages namely GATE, REPORT, REGISTER_REQ, REGISTER and REGISTER_ACK are used for auto discovery and registration of the ONUs. [3]

In DBA_GATED algorithm, the OLT grants the preferred window size to each ONU. Further, if the same ONU has to send more data, it has to send another request to OLT. Though this algorithm provides a high level of QOS, the drawback is that an ONU with more data will block the other ONU with less data. This means ONU with fewer amounts of data has to wait for a long time until the ONU with more data completes its transmission. So in DBA_GATED algorithm, a single user is allowed to meet his demands and standard of service at the cost of other users, which is inequitable. [4]

3. TD-SENSE ALGORITHM

This is a novel algorithm proposed to gauge the performance of the network in terms of variation of both throughput and delay. This is implemented for Triple Play services where delay sensitive and delay non-sensitive applications exist. Video and voice over IP constitute the delay sensitive applications and other multimedia constitute the delay non-sensitive applications.

Delay sensitive application s typically range from 64 to 2500 bytes and are denoted as Type 0 traffic. Delay non-sensitive applications like huge video and data files extend from 5000 to 9000 bytes and are termed as Type 1 traffic. In this algorithm, the report message of all users is stored inside the buffers of the ONUs. The report message may be delay sensitive or non-sensitive.

Let T_1 = time when ONU sends a report to the OLT.
T_2 = time when the report is received at the OLT.
T (0) = Report length of the delay sensitive traffic in bytes or Type 0 traffic
T (1) = Report length of the non-delay sensitive traffic in bytes or Type 1 traffic
Channel free time = $T_2 - T_1$
Four possibilities exist in this approach. The following cases explain how scheduling will be done based on priority.

Case 1: When T (0) > $T_2 - T_1$, then T (0) will be scheduled and T (1) will not be scheduled. This condition indicates that delay sensitive traffic should be scheduled immediately and keeps the non-delay sensitive in buffer to be scheduled in the next cycle.

Case 2: When T (0) < $T_2 - T_1$, then T (0) will be scheduled and T (1) will be scheduled at the channel free time.

Case 3: When T (0) + T (1) < $T_2 - T_1$, then both T (0) and T (1) will be scheduled.

Case 4: When T (0) + T (1) > $T_2 - T_1$ and T (0) < $T_2 - T_1$, then both T (0) and T (1) will be scheduled but report length of T (1) will be cut down so that it can be accommodated in the channel free time.

The traffic generator module generates Type 0 traffic at the rate of $ß_1$ in Gbps and Type 1 traffic rate at the rate of $ß_2$ in Gbps. The offer load ß is given as

$$ß = b_1 ß_1 + b_2 ß_2 \quad (1)$$

Where b_1 = the mean packet size of Type 0 traffic varying from 64 to 1500 bytes.
b_2 = the mean packet size of Type 1 traffic varying from 5000-9000 bytes.

4. NETWOK DEIGN AND TOOLS

The set-up used two 1G Ethernet server adapters which are capable of handling data speeds up to 1.25 Gbps giving a real time functionality. The network uses optical fiber patch cords. In order to emulate a passive optical network two Linux loaded machines, one as OLT (Server Side) and the other as having multiple ONUs in it. Since this resembles a point-to-point network connection rather than a PON, the ONUs and the end nodes are to be simulated so as to follow the PON architecture as shown in the figure [1].

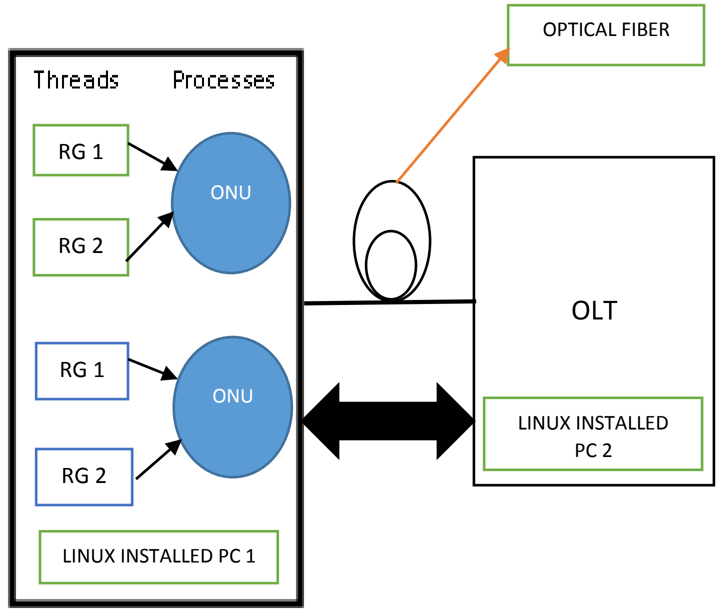

Figure 1: Network Simulation Design

The simulation was carried out by creating multiple processes which act as ONUs and each process has multiple threads running that act as end nodes. The multiple threads randomly generate the traffic. This is similar to the end nodes that generate real time traffic. Thus the entire setup of a passive splitter and the ONUs at different distances is simulated on a single system and the OLT on the other system.

A traffic generator module also known as random packet generator (RG) is used to generate packets and pump them into the network. The rate at which packets are generated is kept random so as to achieve the closest approximation to the real time scenarios. Two traffic generator modules are used in the simulation. The mathematical equation followed for generation of random packets is given as

$$X = -\log(1-\mu) \div \beta_1 \quad (2)$$

Where μ is the random number generated by the system and β_1 is the rate parameter varying from 0 to 1. This traffic generator module follows the exponential function.

The second traffic generation module implemented is based on Pareto Distribution that generates ON - OFF periods. The Pareto distribution is a heavy tailed distribution with a probability density function given by [6]

$$F(x) = \beta_2 * b^{\beta_2} \div X^{\beta_2+1} \quad (3)$$

Where β2 is the shape parameter and b is the location parameter. The number of packets per second (ON period) follows the Pareto Distribution with the rate factor varying from 0.2 to 0.8. The OFF period also follows Pareto Distribution.

Using the above mathematical equations the packet size can be varied using the rate factors β_1 and β_2. Similarly packets of random lengths are generated in the range of 64 and 9000 bytes. Therefore each simulated thread, generates packets of random length at random intervals of time. At the ONU, all the packets were collected and encapsulated into a packet size of 9000 bytes and sent to the OLT. We have used the MTU (Minimum Transfer Unit) to be 9000 bytes. This aids the transfer of packets at higher rates.

5. RESULTS AND DISCUSSION

The results of DBA_GATED and TD-sense algorithms were measured by considering various simulation parameters like delay, data throughput, offered load, traffic type and number of ONUs connected to OLT. Eight ONUs are simulated in one of the systems while the other system has OLT running in it. Exchanging of control messages between OLT and ONU plays an important role for synchronization. It is found that, when the transmission process is on, the low priority control messages get dropped at the socket level of OLT. This occurs because, the OLT, when ready to send data to an ONU1, receives a control message from ONU2. Since the transmission is in progress, the OLT drops this control message from its buffer. As a result, ONU2 starts waiting for the reply and at the same time OLT also waits for the control message from ONU2 which it had sent already. This gives rise to confusion, as OLT and ONU are waiting for each other's responses. To tackle this problem, we modified the communication between OLT and ONU at their socket level. OLT was made to use two sockets of different port numbers to communicate to a particular ONU wherein one socket deals with control message and the other port deals with data transfer. ONU uses the same socket for control message and data.

Packets are generated by various ONUs and transmitted to the OLT. A network bandwidth testing software, 'Netperf' was used to determine average throughput, bytes transmitted and the bytes received with a corresponding delay when the packets move from various ONUs to the OLT. The transceiver cards use 1490 nm as upstream wavelength and 1310 nm as downstream wavelength. The graphs given here (Fig. 1 & 2) show how the TD-sense algorithm is better in performance than the DBA_GATED algorithm. In DBA_GATED algorithm, OLT allocates the time window for the ONU's demands without considering whether the data is delay sensitive or not.

But in case of TD-Sense algorithm, the ONUs are allocated timing windows by OLT as per the report lengths stored in buffer. The data traffic present in the buffer are classified into delay sensitive (Type 0) and delay non sensitive (Type 1). If in a cycle, the buffer contains more number of report lengths of Type 0 traffic than Type 1, then Type 0 utilizes the channel free time. This would lead to Type 1 traffic waiting for subsequent cycles for accessing the channel free time, thus creating bandwidth starvation. TD-sense algorithm solves this by imposing the condition that if Type 0 traffic repeats many times for a given number of cycles, then in the next cycle, the TD-sense algorithm makes Type 1 traffic use the channel free time. Thus it is well suited for both delay sensitive applications like Voice over IP, Video on Demand and delay non-sensitive applications like huge data transfers between users.

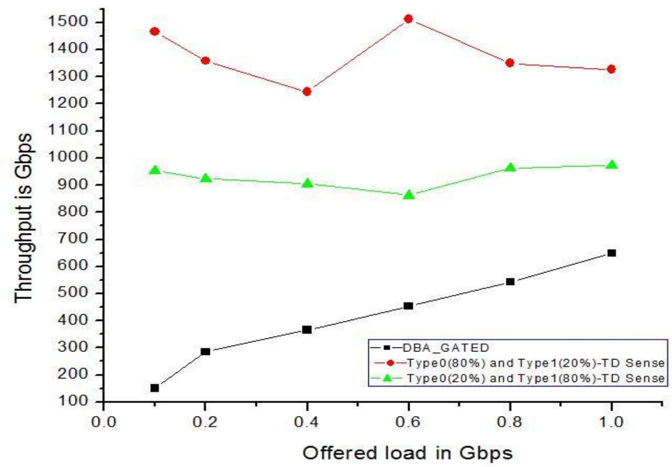

Figure 2: Throughput (Gbps) vs Offred Load (Gbps)

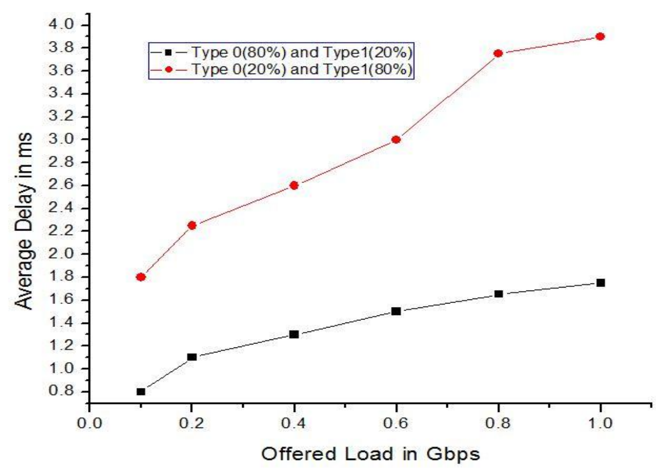

Figure 3: Average Delay (ms) vs Load (Gbps)

Given an offer load, TD-sense algorithm gives better throughput than DBA_GATED algorithm. It can be seen from Fig.1 that when delay sensitive traffic is more i.e., when Type 0 is 80% and Type 1 is 20%, the throughput is maximum in this case. There is a decrease in the throughput when the delay non-sensitive traffic is more i.e., Type 1 is 80% and Type 0 is 20%. In both the cases, TD-sense outperforms the DBA_GATED algorithm.

In DBA-GATED Algorithm the delay increases with increase in offer load. This happens because whatever window size an ONU requests, OLT grants it fully. In case of TD-Sense

Algorithm, the delay is the average delay which is the sum of ONU processing delay, OLT processing delay and Round Trip Delay. It can be seen in Fig.2, that the TD-sense algorithm minimizes the delay when the load is delay sensitive (i.e., Type 0 is 80%) and delay increases when the traffic is not delay sensitive (Type 1 is 80%).

Thus TD-sense algorithm maintains a tradeoff between throughput and delay by classifying the data traffic as delay sensitive and delay non-sensitive. However, we have found that, when the offer load is more than 1 Gbps, the throughput seems to be decreasing, the cause of which is to be explored. This may put a limitation on its applicability for higher offer loads.

6. CONCLUSION

This paper presents a novel ‘TD-Sense algorithm’ for Triple Play Services by simulating semi real access networks with the use of two 1G transceivers and simulating OLT and ONUs in two different systems. It is found that this algorithm maintains a tradeoff between throughput and delay. Bandwidth starvation is overcome in this algorithm. Also, it is more efficient than the DBA_GATED algorithm in terms of the throughput and delay. Real time video relaying through the network and measuring the network efficiency with the increasing number of ONUs can be further explored.

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