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# Efficient Bandwidth Allocation for NG-PON2 based on GBA

S Rajalakshmi*[1], S Balaji[2], A Karthigeyan[3], R Santhakumar[4]

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***Abstract:*** Energy consumption and green endeavours have turned out to be entrenched subjects for cutting edge research work, with particular respect to lessening carbon impression, bringing down adverse impact on the environment, and limiting operational costs. Aside from fitting in with the required societal green plan, there are additionally numerous pragmatic points of interest to making arrangements that show such advantages. Expanding the benefits of energy conservation to high end systems is foremost widely supported for using the Internet application. Different elements of energy conservation in Optical Network, at the user end account for around 70 to 80% of the energy consumed in present Passive Optical Networks. A novel technique is proposed for high end optical system model known as the Next Generation Passive Optical Network-stage2 to save energy considerably by allocating one's Optical Network Unit idle time to other Optical Network Units transceiver occurring in a two-stage system. The Optical Network Units are classified into two categories having different energy-saving modes according to their traffic. The proposed scheme has considerably reduced the Optical Network Unit power consumption and ONU delay. As a result, efficiency increases, power and delay allocation will be applicable for particular available spectrum.

***Keywords:*** *Optical Line Terminal (OLT), Optical Network Unit (ONU), Next Generation Passive Optical Network Stage-2(NGPON-2)*

## 1. Introduction

A novel pairwise combination method proposed to pair any two ONUs by polling the cycle length for low latency DBA. Additionally to that to reduce the PON energy consumption a novel multiple-state energy-saving mode is proposed in the DBA scheme, which produces 2.5 % improved results[1].This paper discusses the ability to provide power to the transmitter and power to the receiver of an optical network unit by newly introduced energy e-client, distributed dynamic bandwidth allocation (DBA) algorithm by keeping the delay bounded across the networks[2].

The work represents a just in time DBA designed for GEPONs networks for two different category of fixed poling time and varying polling time to achieve energy saving in ONU[3].This article uses a proposed efficient framework sleep/doze mode to enhance the energy saving of a WDM PON network. The designed framework is synthesized using dynamic wavelength and bandwidth allocation (DWBA) algorithms [4].

An optical access network designed for ONU interconnection to reduce the energy saving based on electronic switches and the results are compared with optical switches [5]. Sleep mode EPON is studied in Green LRPON for energy consumption reduction in last mile access network[6]. The paper discusses a numerous of research objectives and trade-offs for the plot of energy-efficient and stout optical transport networks from the frame of reference for long-term/short term traffic forecasts and traffic dynamics and Service Level Agreement requirements[7].

Here WDM network designed using a mixed combination of sleep-enabled and non-sleep-enabled router cards for guaranteed traffic. For this design a mixed integer linear programming (MILP) model is proposed[8]. They proposed green LRPON by assigning efficient users to different wavelength in two different types of tree and branch LRPON and ring and spur LRPON to make energy-efficient and to achieve high network utilization[9]. This article illustrates the combination of the tunability and the sleep/doze capabilities by DWBA algorithm to improve the energy-savings in VCSEL present at the OLT/ONU[10]. OFDM-PON is proposed using flexible sleep mode control and dynamic bandwidth allocation[11]. The paper discusses the summary of the research works done by various researcher to reduce energy consumption in various fields such as telecom networks employing the optical technologies in the access level[12].

The paper describes about the integration of silent characteristics of both sleep mode and doze mode in the ONT receiver during turn on/off mode, which results on energy savings by following a novel proposed approach of adaptive watchful sleep mode [13]. The ONUs are rescheduled to a recommended time slot on the basis of fore coming cycle for enhancing the energy saving effect, by introducing a new method that mitigates the gateway of required size for making most of the ONUs entering the inter-cycle sleep mode for medium load traffic effectively[14].

A proposed algorithm designed as Discrete Time Markov Chain for achieving energy efficiency at ONU because of its more diplomacy to the power requirement of doze mode when

[1] *School of Electronics Engineering,*
*Vellore Institute of Technology, Vellore, Tamil Nadu, India-632014*
*ORCID ID : 0000-0001-7609-7505*
[2] *School of Electrical Engineering,*
*Vellore Institute of Technology, Vellore, Tamil Nadu, India-632014*
*ORCID ID : 0000-0002-3364-019X*
[3] *School of Electrical Engineering,*
*Vellore Institute of Technology, Vellore, Tamil Nadu, India-632014*
*ORCID ID : 0000-0001-7805-5739*
[4] *School of Electrical Engineering,*
*Vellore Institute of Technology, Vellore, Tamil Nadu, India-632014*
*ORCID ID :0000-0002-4081-651X*
** Corresponding Author Email: srajalakshmi@vit.ac.in*

comparing to LPM with the outcome of minor sleep-to-wake-up time [15]. A passive optical network with energy saving framework aiming to fuse sleep and doze mode through the dynamic bandwidth allocation algorithms for decreasing ONU energy consumption. Schemes show significant improvement on ONU energy for various evaluation criteria [16].

The paper deigned a QoS-aware energy-saving mechanism implemented in enhanced PON network to decrease the energy consumption in the ONU. To achieve it two sleep durations are proposed in the ONU's Tx/Rx in order to generate four ONU modes including active, transmission, doze, and sleep [17]. In this paper DBA proposed for ethernet PON in the sleep mode putting the ONU in sleep mode designed in two modes of operation one with large sleep overheads and one with small sleep overheads with variety of grant sizing schemes[18].

This article uses a proposed efficient framework sleep/doze mode to enhance the energy saving of a WDM PON network. The designed framework is synthesized using dynamic wavelength and bandwidth allocation (DWBA) algorithms [19]. Energy consumption and green endeavours have turned out to be entrenched subjects for cutting edge research work, with particular respect to lessening carbon impression, bringing down adverse impact on the environmental, and limiting operational costs. Aside from fitting in with the required societal green plan, there are additionally numerous pragmatic points of interest to making arrangements that show such advantages [20].

These developments gave rise to NGPON technology which supports both GPON and 10GPON in the same ODN network. This technology further gave rise to NGPON2 technology. Earlier PONs called Legacy PONs are not as efficient as NG-PON2 when it comes to energy conservation [21]. It explains about the previously used power saving techniques, which considers the energy reduction consumption in NGPON2. Here green bandwidth allocation framework characterised by batch mode transmission incorporated by any one ONU Sleep time computation scheme to achieve maximum energy conservation[22].

A proposed new MAC that switches the PON system to a slotted one from inActive mode to Active mode to reduce the power conception, when the traffic is in the light load by using a Markov Model. Results show that ONU is having 20 Mbps bandwidth even for 3% of its time is in working state condition[23]. This article discusses about the summary on energy conservation using the cyclic sleep mode for the ONU's available in PON networks in present and future generation networks [24]. To increase the speed for private and public networks the bandwidth is dynamically allocated using switching logic in wavelength division multiplexing based Long reach passive optical networks[25]. This paper discusses the design of energy efficient WDM/TDM PON network architecture by allowing adaptive bandwidth allocation to reduce the power consumption[26]. The paper discusses comparison of Optical Active Network with optical switches and OAN with electronics switches showing considerable energy consumption [27].

The following section describes about the classification and methodology and next section discuss the bandwidth allocation and next section discusses results and finally conclusion and references.

## 2. ENERGY SAVING TECHNIQUE

When it comes to Software-based techniques is shown Fig.1, the energy conservation techniques can be classified as

Power Shedding technique: In this technique the ONU turns off some of its devices whose function at that moment is not required, but the optical link is left at full function. Therefore, this mechanism only saves minimal energy.

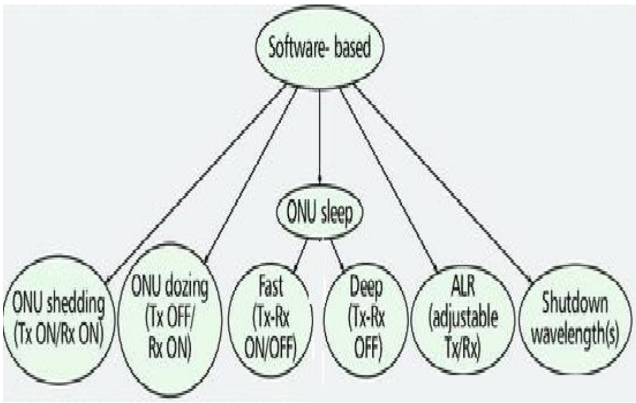


**Fig 1**. Classification of Energy Saving Technique

Doze Mode: Here the transmitter of the ONU is turned off, but the receiver is at full function. It is efficient when the ONU has no information to send to the ONU. However, it still isn't the most efficient method since the receiver is not expected to turn off.

Sleep Mode: It is the mechanism in which the ONU transmitter and ONU receiver are switched off. It is further classified into 2 types:

Deep Sleep: ONU transmitter and ONU receiver are switched off when no transmission is taking place between the OLT and the ONU. This mechanism has the potential to conserve maximum energy but can also lead to loss of information as some packet can be dropped.

Cyclic/ Fast Sleep: In this mechanism, the ONU switches between Sleep and Active state. The time comprising of the Active and Sleep period is called Sleep cycle. This mechanism is efficient when it comes to energy conservation depending upon the Dynamic Bandwidth Allocation and appropriate Sleep period.

Lately, energy utilization in NGPON2 draws the attention from the industry and scholarly world. NGPON2 framework was characterized as Active, Doze and Sleep mode for energy saving in passive optical network, each ONU can toggle between these modes during its transmission rate and receiver rate, which decrease energy consumption of ONU when there is nill transmission of information is required.

In conventional energy conservation technique, each and every ONU is allotted a fixed downstream and upstream transmission windows, which could be overlapped in order to receive information from OLT or to transmit information to OLT. When transmit and receive windows of ONU are not coinciding, one side will occupy the time slot which stays in idle state, and also not bandwidth-efficient and introduce more amount of delay to entire system.

In this article, a two-stage energy saving scheme is proposed, which allows the downstream and upstream ONU transmission windows to be used by other ONU transmission window, which is called Upstream and Downstream Matching (UDM) technique. Each ONU can enter Sleep and Doze mode by utilizing this technique to indicated their data transfer capacity prerequisite as the same as past energy conservation scheme. In the meantime, OLT will dispense the one ONU idle time to other ONU which leads to efficient use of bandwidth and ensures the QoS necessities. The Bandwidth is allocated through the Green Bandwidth Allocation Algorithm and the Sleep period is calculated by through the Sleep Mode Aware Algorithm which are explained in detail in the rest of the paper. Furthermore, a system of Interference Power Control Using Distributed Stream Analysis is proposed to reduce the power consumption and delay factor using Dynamic Bandwidth Algorithm.

## 3. Methodology

To transmit and receive data either from/to ONU nor OLT within a system a fixed time slot is allotted which is efficient only for symmetric transmission windows. In today's world the transmission window is rarely symmetric. For example uploading a video on the internet or HDTV signals, the transmission windows are not symmetric. This leads to a considerable delay in the transmission of data. This delay is reduced substantially by the Downstream Upstream Matching (DUM) technique where the ONU can share the idle time of another ONU to send or receive data from OLT.

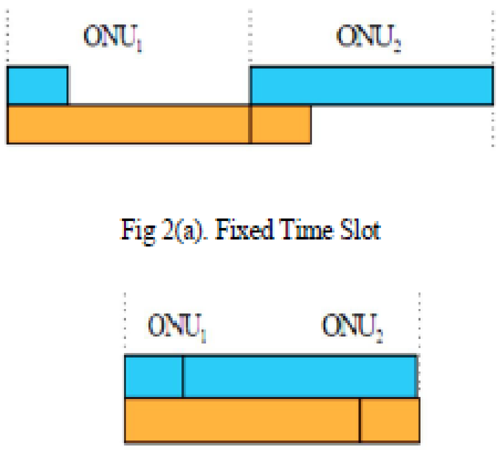


**Fig 2(a).** Fixed Time slot
**Fig 2(b).** Upstream and Downstream Matching Techniques

In the above Fig.2(a), represents the Fixed time slot allocation technique is compared with the Fig.2(b) where the total time, ie the total transmission time in case of UDM scheme is less as the ONU idle time is allocated to another ONU. To improve the performance of the network, particularly to increase bandwidth utilization and efficiency, we have implemented Most Fit First Algorithm (MFFA) technique based on UDM, where the OLT first polls the ONU before allocating the Sleep period.

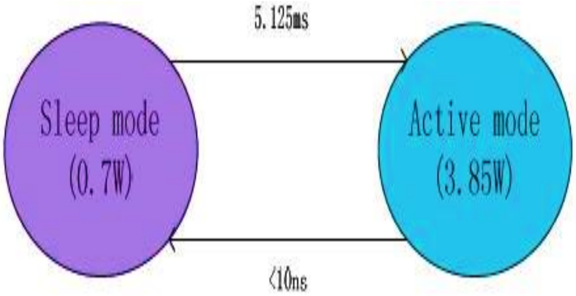


**Fig 3.** State Transition model between the Sleep and Active Mode of ONU

Fig 3. Shows the State Transition Model between Active and Sleep mode of ONU. The most energy conservation can be achieved in Sleep mode but it also compromises the QoS as there can be loss or drop of information if a delay sensitive information is present. This tradeoff between the QoS and energy conservation is critical. When considering the light load traffic, the delayed data is transmitted first, since it is very sensitive, following that, the remaining data is transmitted, which is not sensitive. During this time the ONU enter the Sleep mode with some extra delay. The Sleep period is calculated by GBA and SMA which is based on incoming traffic rate and queue state of OLT and ONU respectively. In order to prevent packet loss, the incoming upstream and downstream data must be buffered at the ONU and OLT with the overhead shown in fig 2(b).

Next while considering the heavy load traffic, the ONU enters the Doze mode. During the current cycle, the data is uploaded based on Time scheme which makes the ONU to enter to energy saving mode. It is obtained by enabling the ONU to transit from Doze mode to Active mode with acceptable grade of Qos metrics and must be less than 64 ns. The condition is that the ONU must wake up before the transmission of next OLT communication starts.

### 3.1. OLT has two phases in each polling cycle.

In the first phase, bandwidth allocation is decided by OLT for each ONU for both stream of direction, before each polling starts, since to prevent bandwidth cartel in case of high load ONUs. The DBA service is used to calculate the time slot, maximum bandwidth of ONU. The light load ONU are calculated using (1) and high load ONU are calculated using (2).

For Light Load ONU,

$$DS_{B,}\, DS_{B,} < B_{max}\, x\ light\ load\ constant \quad (1)$$

For High Load ONU,

$$DS_{B,}\, DS_{B,} > B_{max}\, x\ high\ load\ constant \quad (2)$$

where $DS_B$ and $US_B$ is the downstream bandwidth and upstream bandwidth. Light- load constant is the ratio of traffic load. The value varies from 0 to 1.

In the Second phase, to increase the network performance by increasing the bandwidth allocation, the OLT uses Most Fit First algorithm (MFFA). It determines the ONU polling orders to minimize the total energy preserving

In each polling cycle, specific ONU, experiences four phases:

(a) At the starting of Polling cycle, the non-sleep ONU receives the GATE messages from the OLT. The ONU transmission starting time and its window size is given by GATE messages for both directions

(b) The ONU gets the information of success transmission windows and then switches to Doze mode after receiving the GATE message.

(c) When the transmission window finishes the clock synchronization with the OLT, the ONU wakes up. After synchronization OLT and ONU transmit traffic to each other. ONU sends the REPORT message after receiving the upstream traffic.

(d) When both the downstream and upstream data finishes its transmission, the ONU goes into Sleep or Doze mode. The Sleep control message is present inside the GATE message, which decides to enter into either Sleep or Doze mode.

### 3.2. Green bandwidth allocation (gba)

To Switch the ONU into Sleep mode for specific period of time, Green Bandwidth Allocation is used to send or receive a burst of stuffed downstream and upstream data, before the ONU goes into wake up state. The importance of this allocation is to save the energy, by having a longer Sleep period and sorter overhead time. By increasing the ONU Sleep time the total overhead time is reduced. The total active time consumed is 40 ms for transmitting 40 Gbps of data.

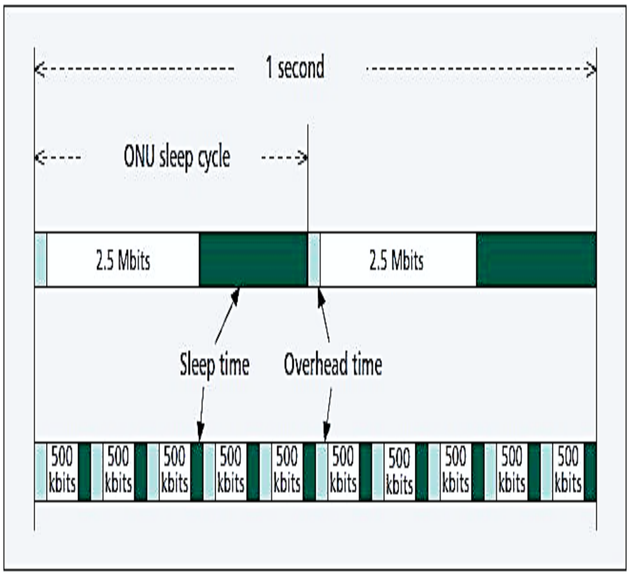


**Fig 4.** Transferring 40 Gb/s traffic using BGA (upper diagram) and legacy-mode (lower diagram) transmissions

Fig 4 shows the diagram of 40 Gbps traffic using BGA (upper diagram) and legacy-mode (lower diagram) transmissions. When comparing with the conventional scheme, the total over head of proposed BGA is 10.25ms, which is limited by a factor of 5 times. To save maximum energy, the criteria is to increase the ONU Sleep time, but while increasing it, the QoS for delay sensitive application reduces. Therefore a trade of must be maintained between ONU Sleep time and QoS.

### 3.3. GBA at OLT

When applying the GBA algorithm to the OLT, the ONU Sleeping mode is initiated. The GBA procedure is as follows

Step 1: While all the ONU gets the request message, OLT has to wait.

Step 2: The ONU Sleeping time and the maximum delay time is to be computed next.

Step 3: Next transmit the downstream data to the ONU within the allocated upstream widow

Step 4: Next is to transmit the grant message to all ONUs with Sleep time value.

### 3.4. GBA at ONU

When the GBA is applied to the OLT, the ONU goes into the Sleep mode and sets the timer as soon as it receives the grant message. The operation shows direct ONU transmission scenario and Sleep request scenario is applied to the active ONU period.

Direct ONU transmission: The ONU after waking up starts sending the messages. Fig 5 shows the ONU total overhead occurring during Sleep cycle is low as it does not have any waste idle time.

Sleep request: As soon as the ONU wakes up, upstream direction request is sent and it has to wait till it receives an OLT grant. Request-grant procedure causes incremental delay as in fig 5, and must be added in the computation of the Sleep time, to reduce the energy efficient.

With either scenario, after sending the request message to the OLT, each ONU will remain idle until receiving a grant message from the OLT. ONU remains idle until it receives OLT grant message. In order to save energy, the OLT requires grant message for two sleep times

First Sleep time is based on OLT, which specifies the ONU time, which is used to receive the grant message in Sleep mode.

Second Sleep time is based on ONU, which specifies the ONU time spends in Sleep mode after sending and receiving a grant message

To maintain the QoS performance the sum of the both Sleep times must of exceed the computational maximum Sleep time. If the Sleep time is short, it has slow recovering data. To overcome this issue Sleep time must be greater than overhead time. With this methods, GBA can achieve the maximum possible energy reduction.

### 3.5. Sleep Mode Aware Algorithm

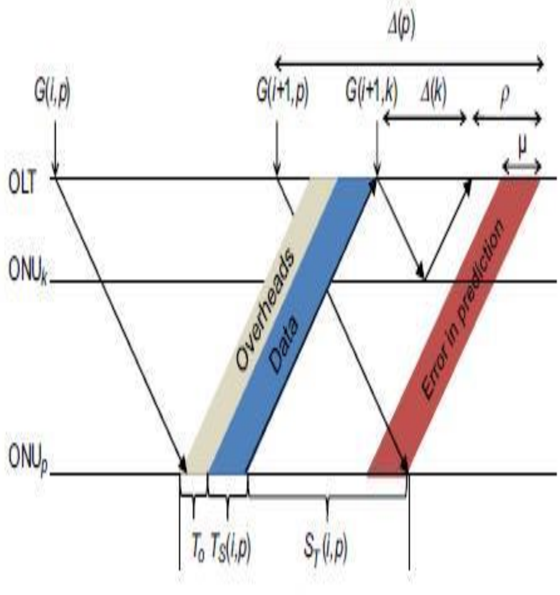


**Fig 5.** GATE prediction using the GBA algorithm

During the activity slot of an ONU only the downstream OLT data is transmitted. The ONU Sleep time, 'p' is calculated using (3)

$$G(i+1,p) = G(i+1,k) + \Delta(k) - \Delta(p) + p \quad (3)$$

Where GATE G (i, p) is time epoch of present, G (i+1, p) is the time epoch of next GATE, Transmission slot is $T_s$ (i, p), and Sleep overheads $T_0$ of ONU. Also where Δ(p) is the round trip time of ONU and P is the transmission slot of the remaining ONUs (the ONUs whose REPORTs do not arrive)

The OLT knows the three components of Sleep time. But the time is not known for issuing the GATE message for the forth coming cycle for an ONU, i.e., G (i+1, p), which may not be known at the time of issuing the present GATE message.

## 4. Simulation and Results

The proposed scheme's performance is compared with the performance of the Fix Time Slot while making the ONU downstream and ONU upstream transmission windows to be consistently overlapped. It enters doze mode when transmitter is idle in terms of power saving and packet delay for both the downstream and upstream.

To throwback the property of the real scenario of internet cloud traffic, the light-load-ONU and high-load-ONU are made to synchronize in the PON system. The PON system is simulated for asymmetrical and symmetrical load. Asymmetric load means in every ONU, the upstream load and the downstream load varies. In the entire network the total upstream load is equal to the downstream load.

The performance comparison of the two schemes is depicted in fig 3 with the various ratio of light-load-ONU. From Fig.3(a) it is easily depicted that the downstream and the upstream delay of the proposed scheme is 50% decreased than Fix Time Slot in the high load traffic. When there is a increase of the load of the high-load-ONU, delay difference of the two schemes becomes larger.

It is due to the proposed-scheme allocating more idle time of one ONU's transceiver from another ONU transceiver, while reducing the total transmission time and reduction in certain delay in every cycle. From the Fig.3(a) that the energy saving percentage of high-load-ONU for the proposed-scheme is almost same with Fix Time Slot which reduces with the increment of the load of the high-load. As a result of both schemes entering doze mode based on Just In Time scheme after transmission, but the energy saving percentage of light load-ONU for the proposed-scheme that ONUs enter sleep mode based on GBA in the light load traffic is higher than Fix Time Slot that ONUs always enter doze mode after transmission, according to Fig.3(b) which is about 75% and 50% respectively.

In Interference Power Control Using Distributed Stream Analysis, based on the signal interference noise ratio the power consumption of transmitter and receiver will be very less. As a result efficiency will increase and power and delay allocation will be applicable for particular available spectrum.

To improve the bandwidth utilization efficiency, we use GBA based on UDM, which reduces the transmission delay upto 50% and saves 75% of the energy. During the heavy load traffic, ONU enters Doze mode based on Just in Time Scheme. By decreasing the load, energy saving percentage increases.

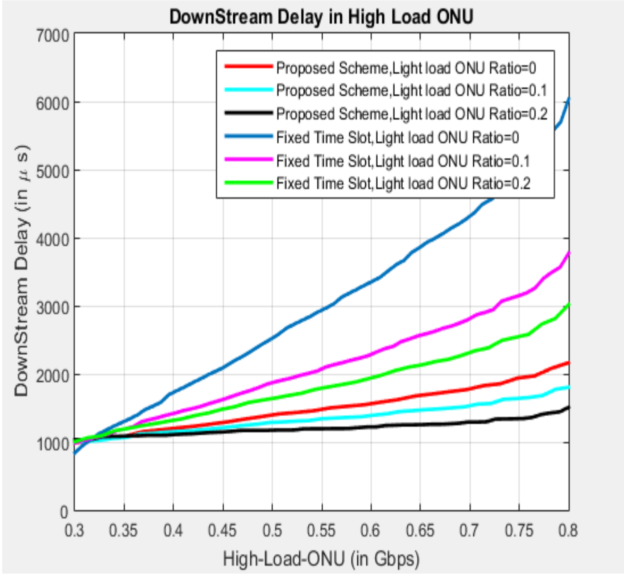


**Fig 6.** Downstream Delay vs High Load ONU under different light load conditions High Load ONU

Fig 6. Shows the simulated results obtained using the UDM Algorithm for heavy load operated under different light load ratio conditions such as 0.1 and 0.2. The simulation is also compared with the fixed time slot method. The results shows that the downstream delay is less than 2000 µs. When the light load ratio comes to 0.2 the delay still more reduces to 1000 µsec.

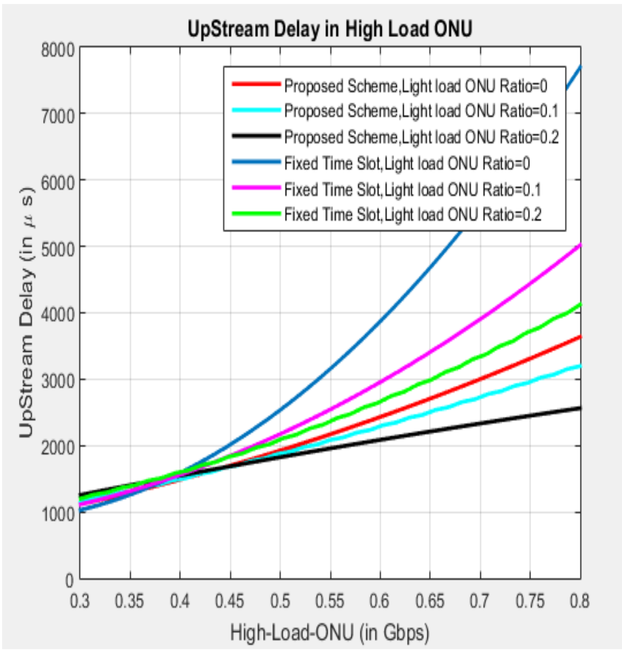


**Fig 7.** Upstream Delay vs High Load ONU under different light load conditions

Fig.7. Shows the simulated results obtained using the UDM Algorithm for heavy load operated under different light load ratio conditions such as 0.1 and 0.2. The simulation is also compared with the fixed time slot method. The results shows that the upstream delay is less than 3000 µs. When the light load ratio comes to 0.2 the delay still more reduces to 2500 µsec.

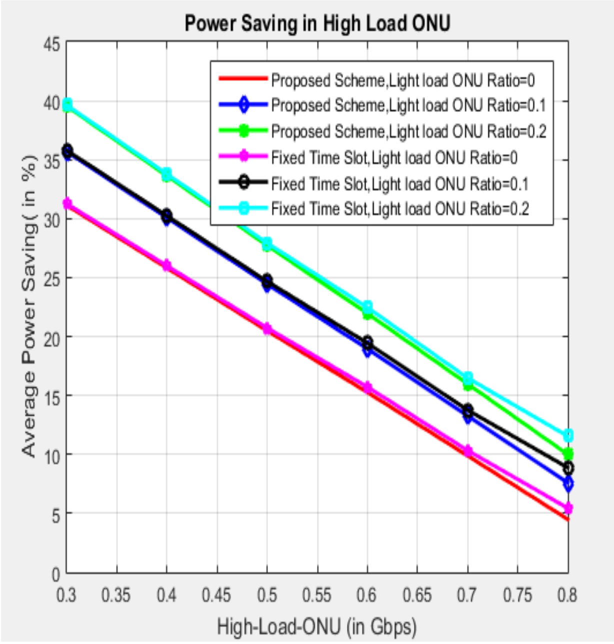


**Fig 8.** Average power saving vs High Load ONU under different light load conditions

Fig 8 Shows the simulated results obtained using the UDM Algorithm for heavy load operated under different light load ratio conditions such as 0.1 and 0.2. The simulation is also compared with the fixed time slot method. The results shows that the average power saving is increased from 0 to 40 % when the high load ONU is increases from 0.3 to 0.8.

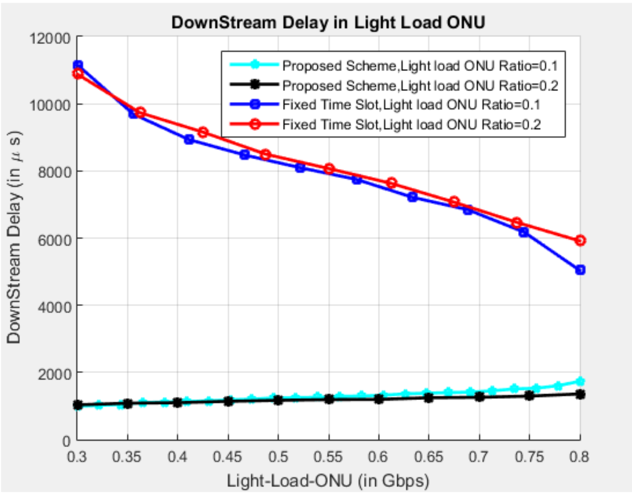


**Fig 9.** Downstream Delay vs Light Load ONU under different light load conditions.

Fig.9. Shows the simulated results obtained using the UDM Algorithm for light load operated under different light load ratio conditions such as 0.1 and 0.2. The simulation is also compared with the fixed time slot method. The results shows that the downstream delay is less than 2000 µs. When the light load ratio comes to 0.2 the delay still more reduces to 6000 µsec.

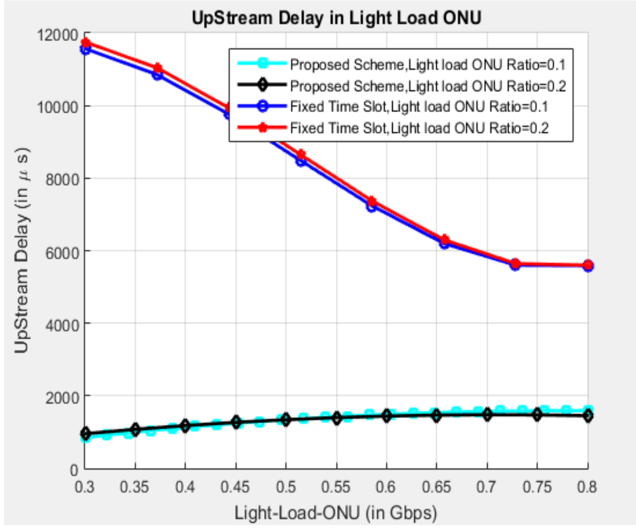


**Fig 10.** Upstream Delay vs Light Load ONU under different light load conditions

Fig 10 Shows the simulated results obtained using the UDM Algorithm for light load operated under different light load ratio conditions such as 0.1 and 0.2. The simulation is also compared with the fixed time slot method. The results shows that the upstream delay is less than 2000 µs. When the light load ratio comes to 0.2 the delay still more reduces to 6000 µsec.

Fig.11. Shows the simulated results obtained using the UDM Algorithm for light load operated under different light load ratio conditions such as 0.1 and 0.2. The simulation is also compared with the fixed time slot method. The results shows that the Average power saving is more than 75%µs. When the light load ratio comes to 0.2 the minimum power saving obtained is 0%.

In the system of Interference Power Control Using Distributed Stream Analysis, we are going to reduce the complexity of allocation of power to each receiver and transmitter. So based on the signal interference noise ratio the power consumption of transmitter and receiver will be very less. As a result efficiency will increase and power and delay allocation will be applicable for particular available.

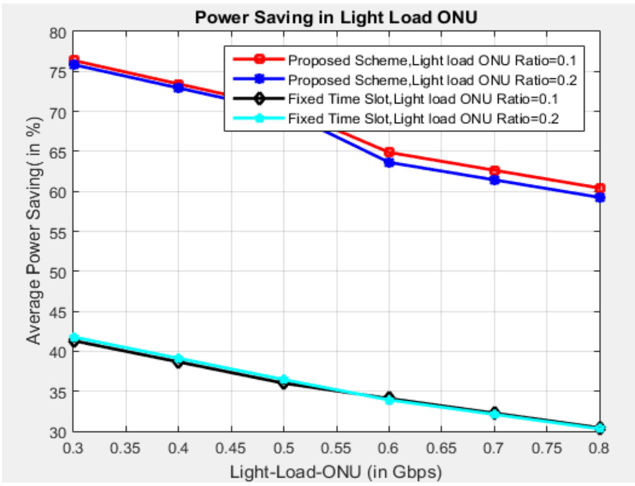


**Fig 11.** Average power saving vs Light Load ONU under different light load conditions

## 5. Conclusion

In this work the bandwidth utilization efficiency is improved by the implementation of the DBA based on UDM. The proposed method proves 50% reduction of the upstream and downstream delay in the ONU high load. 75% of the energy saving is achieved during ONU light load traffic as it enters the sleep mode. ONU can enter the Doze mode, in the current cycle after uploading its data based on Just In Time scheme, during the high load traffic situation. In the system of Interference Power Control Using Distributed Stream Analysis, we are going to reduce the complexity of allocation of power to each receiver and transmitter. So based on the signal interference noise ratio the power consumption of transmitter and receiver will be very less. As a result efficiency will increase and power and delay allocation will be applicable for particular available spectrum.

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