

# Scaling Technique of Triple Play Services in Passive Optical Network using Subcarrier Allocation Algorithm

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**Abstract**— Data consumption increased sharply, all triple play services such as Voice, Data-Internet & Video can be performed on one communication path, even fiber optic has also bandwidth limitations, previous studies tried to maintain the fairness among the users, but there is no fairness of service therefore the allocation of data transmission must be optimized as their needs. A Passive Optical Communication in downstream direction are presented. We proposed to modify current burst methods to scheduling distribution SC on system OFDM from OLT to ONU by utilize FDMA to allocating SubCarrier based on the services are applied. Significant gain of bandwidth efficiency up to 60% obtained when link is being congest.

**Keywords**— FDMA; O-OFDMA; Fairness Services; Scalable; Triple-play, Subcarrier Allocation

## I. INTRODUCTION

End-to-end communication with optical network media is not expensive anymore. Personal users can now use the fiber technology to pass the triple-play services at once, for video, internet data, and telephone. These three services have different characteristics in terms of bandwidth consumption demand [12]. Therefore, it needs different scale setting on the data sent to every services in which the optic technology did not apply the fairness standardization among the delivered services.

Previous studies [1] and [6] tried to maintain the fairness among the users with O-OFDMA + TDMA in downstream Passive Optical Network (PON) system with main techniques, namely burst and circuit modes. In terms of fairness on the user, there is a good result, but there is no fairness of service with different bandwidth consumption need. Therefore, this research offers OFDMA + FDMA system through optic channel with additional scalable algorithm to maintain the fairness of service by giving different scalability on the triple-play main services.

The importance of maintaining fairness among the services using FDMA is to provide the portion of bandwidth by allocating the different portion of SubCarrier (SC) for every type of services as needed. We proposed scaling technique by giving different priority scale, it is expected that the services will get different throughput, so the fairness of service will be achieved. This research will be simulated in downstream direction, with

the two scenarios, in the normal usage and in the overload usage cause of number user online at the same time. Throughput per services will be compared between current PON system and proposed system.

## II. NETWORK ARCHITECTURE & NODE STRUCTURE

Proposed system design is O-OFDM + FDMA with additional algorithm to determine the policy scalability as shown by diagram block in Fig. 1. The simulation channel model is conducted in optical access system by PON system with downstream direction using 1 port OLT toward a number of ONUs (users) as shown in Fig. 2. FDMA following OFDM used to allocates SC for three types of traffic pattern which previously detected and assumed as three service types with the determined policy. Then it is distributed evenly to all users with Fix Burst Transmission (FBT) method.

With the aforementioned system design, the simulation will be conducted with Matlab and performance indicator in form of fairness index and throughput on the sent service type; the throughput will compare the throughput between the number of ONU in every service type. For the comparison, the simulation of current PON system in downstream direction will be conducted too.

Unlike the studies [1] and [3] with the combination of O-OFDM + TDMA system based on the time, this research uses the sub-carrier division by combining the O-OFDM + FDMA system for the categorization based on the sub-carrier.

FDMA in general, allocates the sub-carrier in order to differentiate the target users, while this research is proposed to utilize the FDMA by allocating the sub-carrier based on scale that determined for different three types of services.

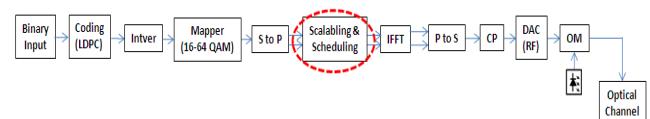


Fig. 1. Downstream Diagram Block from OLT with additional Scaling Process

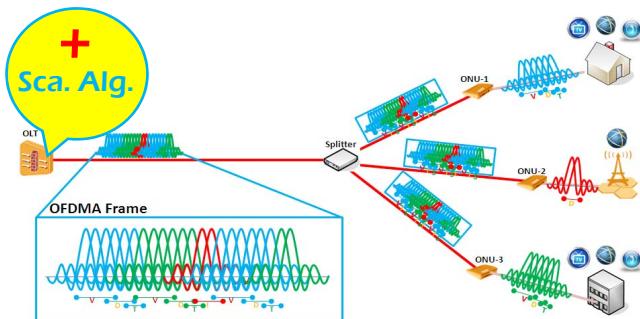


Fig. 2. Single-wavelength Optical OFDMA-PON architecture  
Modified from : Cvijetic, N.; "OFDM for Next Generation Optical Access Networks"; NEC labs

To make the simulation more general, we consider the triple-play traffic model with: 1) variable bit rate (VBR) traffic for video applications as V traffic; 2) constant bit rate (CBR) traffic for voice/PWE/TDM applications as T traffic; 3) self-similar data traffic for internet access applications as D traffic.

Due to the difference character of the bandwidth consumption for all types of services, as had been predicted by several sources, such as in [12], in addition we can see the amounts of consumption based system network, whether via mobile network or fixed network, we can also see the amount of bandwidth consumption per category sub segment of the services consumed. As seen in Table 2.1. In order to ensure that they get the bandwidth to the extent needed, from which we try to approach by dividing the service into triple-play main service, and determines the amounts required by the three types of service. And obtained a score of 6: 3: 1 as shown in table 2 column *portion average per segment and scale assumed*.

Consumer Internet Traffic, 2014–2019							
	2014	2015	2016	2017	2018	2019	CAGR 2014–2019
<b>By Network (PB per Month)</b>							
Fixed	31,45	37,908	46,511	58,115	72,933	91,048	24%
Mobile	2,050	3,430	5,599	8,906	13,587	20,544	59%
<b>By Subsegment (PB per Month)</b>							
Internet video	21,624	27,466	36,456	49,068	66,179	89,319	33%
Web, email, and data	5,853	7,694	9,476	11,707	14,002	16,092	22%
File sharing	6,090	6,146	6,130	6,168	6,231	6,038	0%
Online gaming	27	33	48	78	109	143	40%

Table 1. Global Consumer Internet Traffic, 2014 - 2019  
Source: Cisco VNI, 2015

Consumer Internet Traffic, 2014 - 2019							
	2014	2015	2016	2017	2018	2019	
<b>By Network (PB per Month)</b>							
Fixed	31545	37908	46511	58115	72933	91048	
Mobile	2050	3430	5599	8906	13587	20544	
<b>By Subsegment (PB per Month)</b>							
Internet Video	21624	27466	36456	49068	66179	89319	Service Type
Web, Email, and Data	5853	7694	9476	11707	14002	16092	
File Sharing	6090	6146	6130	6168	6231	6038	
Online Gaming	27	33	48	78	109	143	
Voice							Portion Average per Sub segment
							Scal e Assu med

Table 2. Scale of Triple-play Services

### III. SCALING & ALLOCATING SCHEME

The scheduling scheme theory has three stages according to [7], namely classing, marking, and queueing, as seen in figure-3. classing is the recognition classification on the accepted traffic pattern, based on [3] traffic difference types, they are Constant Bit Rate (CBR), Variable Bit Rate (VBR), and self-similar data traffic. Paper [8] describes that CBR is the traffic pattern form in the similar data pattern and there are only few changes. The pattern is in the Voice and the inanimate video. Meanwhile, the traffic pattern in VBR changes more frequently and this pattern is often found in the transmission of video data. The last type is self-similar data traffic that is often used for general data pattern in the process of general internet access. Marking is the process to mark the classified traffic; it is differentiated based on the traffic pattern to manage the next process. The last is the Queueing process in which this process allocates the traffic into every sub-carrier based on its service types, by Scaling & Allocate it.

In this research we assume that first two stages are done. The output that will be used as the input of 3rd stage is a data with the information of service type that will be queuing to deliver to ONUs after they occupied the SC that has been allocated by using the additional scaling algorithm.

By approaching to the data from [12], we are grouping the traffic of sub segment service that consumed by user global into three types of services and normalized it, then the value we use as a reference to allocate scale number of SC each type of services. Their scale are 6 SC for VBR traffic pattern or general video data, 3 SC for self-similar data transmission or general for internet access, and 1 SC for CBR or general for voice (telephone).

The ideal allocation is when the bandwidth scale required does not surpass the available line rate. When the required bandwidth exceeds the provided line rate, the following calculation is applied.

$$N_2 = \sum_n^1 UBW_{\text{Max}} \quad (1)$$

$$V = \left[ \frac{N_1}{N_2} * 6 \right]; V \cong 0, V = 1 \quad (2)$$

$$D = \left[ \frac{N_1}{N_2} * 3 \right]; D \cong 0, D = 1 \quad (3)$$

$$T = \left[ \frac{N_1}{N_2} * 1 \right]; T \cong 0, T = 1 \quad (4)$$

$N_1$  is the available line rate,  $N_2$  is the number of required bandwidth,  $Ubw_{\text{Max}}$  is bandwidth set on every ONU, and  $V, D, T$  are the service types for Video, Data and Telephone/Voice.  $V, D$ , and  $T$  are the absolute values with the round down. If the round down results in value 0, the minimum value, 1 will be allocated.

After 1 cycle on ONU/first user (U1) is allocated, the allocation shifts to ONU/2nd user (U2), and so on until the last ONU ( $U_n$ ). When the line rate is still available, the scheduling will allocate again to U1, U2, and so on until the bandwidth is achieved or the line rate runs out.

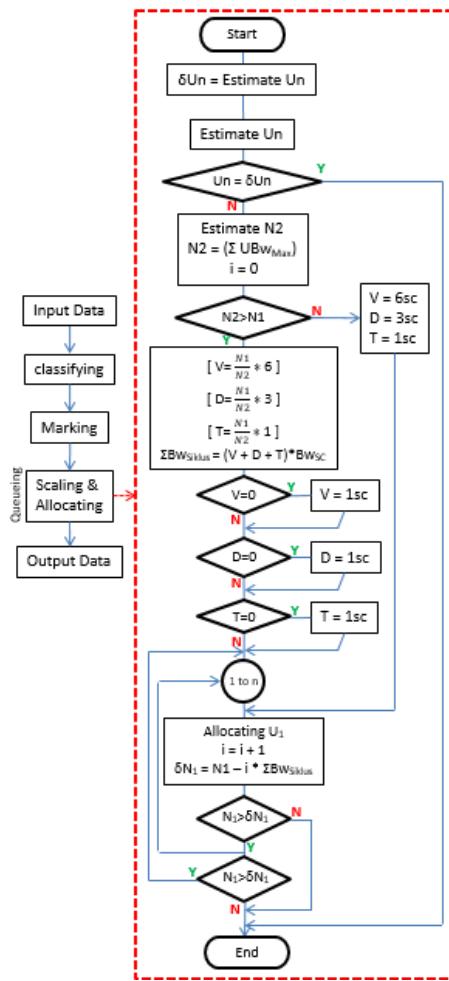


Fig. 3. Flowchart proposed system

As mentioned previously that two process before as classifying and marking are assume that have been done. In queuing process, it will start by giving value of data  $U_n$  with existing  $U_n$  which it the first time it will be zero value and continue to estimating  $U_n$ . Estimating  $U_n$  is count the input of how many users online at the same time. Then, it will compare is  $U_n$  has the same value with  $dU_n$ , if yes, then it is end of process, but if not, then continue to next process, estimating  $N_2$ .  $N_2$  is sum of all allocated BW ONU, while  $N_1$  is Bandwidth capacity of port OLT. If  $N_2$  is smaller than  $N_1$ , then all services will allocate the default value of sub carrier, 6 SC for video ( $V$ ), 3 SC for data ( $D$ ), and 1 SC for telephone ( $T$ ). However, if  $N_2$  is bigger than  $N_1$ , then it should be normalize as formula (2), (3),&(4). And as SC in a real number, so it has to anticipate that it could be lower than 0, it will allocate 1 SC for each minimum services.

After determining allocation SC for each service, then next process is distribute the data following allocated SC by using round robin distribution. And by using formula (6), it will check how much the rest of idle line rate ( $dN_1$ ).

User Type	Services Consumed	SC Allocated
1	Video only	6
2	Data only	3
3	Voice only	1
4	Video + Data	(6 + 3) = 9
5	Video + Voice	(6 + 1) = 7
6	Data + Voice	(3 + 1) = 4
7	Video + Data + Voice	(6 + 3 + 1) = 10

Table. 3 Type of user by services consumed

$dN_1$  is used to maintain the cycle, by comparing with the  $N_1$ , it will repetition number of users who are online, then be repeated back until customer ONUs bandwidth is reached, or OLT line rate bandwidth full-filled. The flowchart shape from scaling and scheduling is shown in Figure 3.

The data type are conduct of differential random user services consumes and the random bandwidth applied on ONUs. To make it measurable, we define type of user consume services. There are seven types of user that will be applied randomly to ONUs, they are users that only consume video, users that only consume data, users that only consume telephone, users consumes video and data, users consumes video and telephone, users consumes data and telephone, and users consumes all three kind of services as shown at table 3. in addition to define type of user, to make it measurable, we also define the amount of bandwidth of user leased. There are eight amount of bandwidth that will be applied randomly to ONUs, 1Mb, 2Mb, 3Mb, 5Mb, 10Mb, 20Mb, 50Mb, and 100Mb.

#### IV. PERFORMANCE STUDIES

To evaluate the proposed system, this scheme is conducted on the network of element access with one port of active OLT and distributed over optical passive splitter to several ONUs. The simulation scenario will be approach to the real environment which random user services consumes and random bandwidth amount applied on ONUs.

Proposed simulation uses two scenarios, when there is a normal usage with the ONU online number that can be accommodated by line rate of OLT (set 32 ONUs), and when the maximum number of ONUs are used (set 128 ONUs). The result of total throughput per services and average of throughput per services/user will be compare between current PON system and proposed system. as seen on figure 2, Proposed system is adding the Scaling Algorithm.

Global standartization of requirement are implemented, 1Gbps for linerate of OLT, 256 Kbps for size of SC. 100 times repetition on each skenario are applied to obtain the normalized value.

First result of simulation as seen on figure 4 & 5 are comparing mean throughput per services per user in normal condition, and figure 6 & 7 are comparing mean throughput services per user in congestion condition.

in figure 4 & 5, we can see how much portion bandwidth allocated for every services, and except the different of

bandwidth portion of each services, total bandwidth allocated to the users are same.

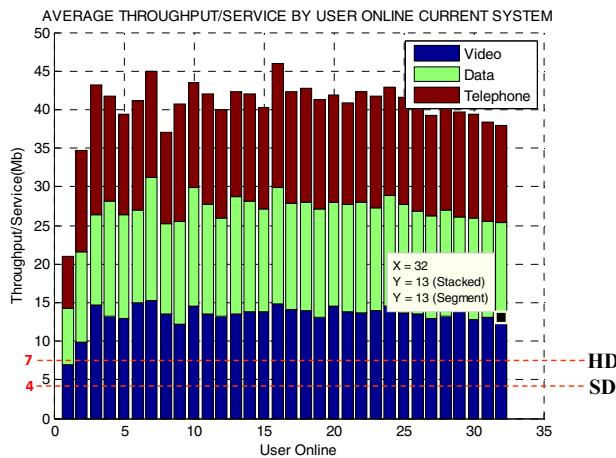


Fig. 4. Mean throughput per service per user at normal condition in current PON system

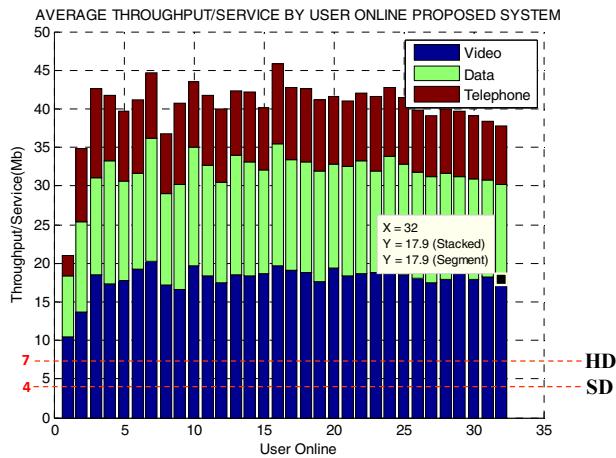


Fig. 5. Mean throughput per service per user at normal condition in Proposed PON System

In the normal condition, we compare both systems with two qualities of video services, they can handle both video format quality SDTV (required 4Mb) and HDTV (required 7Mb) at 32 users online at the same time.

In figure 6 & 7, it seen that bandwidth allocated for video in current system cannot handle both video format quality of SDTV and HDTV when all 128 users online at the same time, but in the proposed system all 128 users online still can enjoy video in format quality SDTV(required 4Mbps), and Video quality HDTV(required 7Mbps) can be enjoyed by 125 users online at the same time where in the current system can be enjoyed by 75 users online

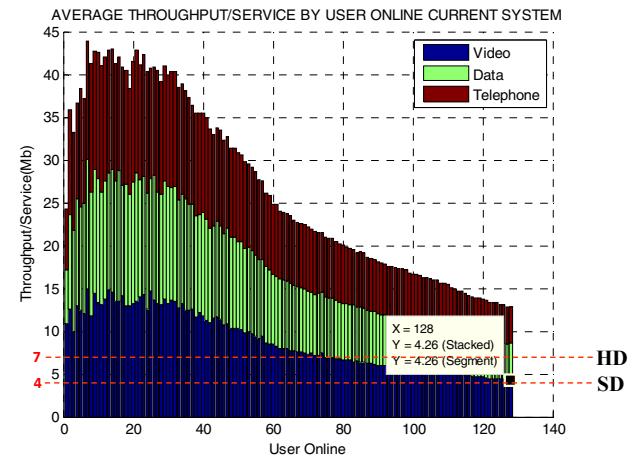


Fig. 6. Mean throughput per service per user at overload condition in current PON system

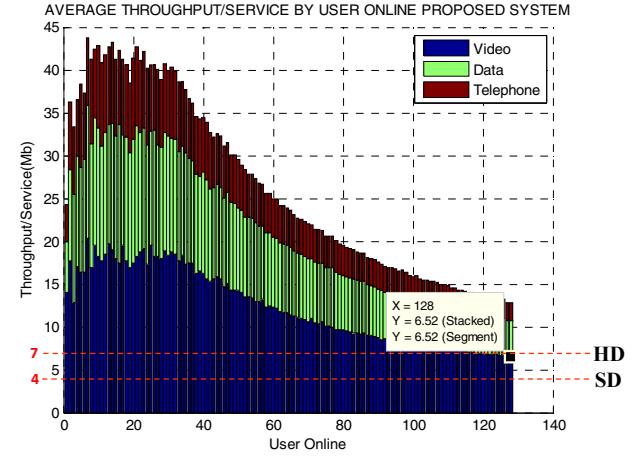


Fig. 7. Mean throughput per service per user at overload condition in proposed PON system

Second result of simulation can be seen on figure 8 & 9 that comparing throughput per service in congestion condition.

As we can see by using proposed system in figure 9, it is more stable and even both of result are cannot meet the congestion point at  $10^9$  (1Gb), but if we see how much user online will consume about 90% of line rate from 1Gb in current system is 53 users online, and 85 users online in proposed system, about 60% gains of efficiency achieved by using proposed system.

From all figure mention before, we can see both measurement as a mean bandwidth services per user or total bandwidth services, we got efficiency gain in bandwidth usage by using proposed system than current system.

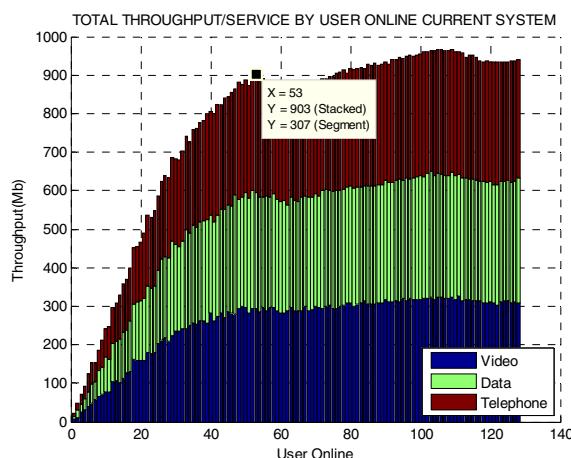


Fig. 8. Total throughput per service at overload condition in current PON system

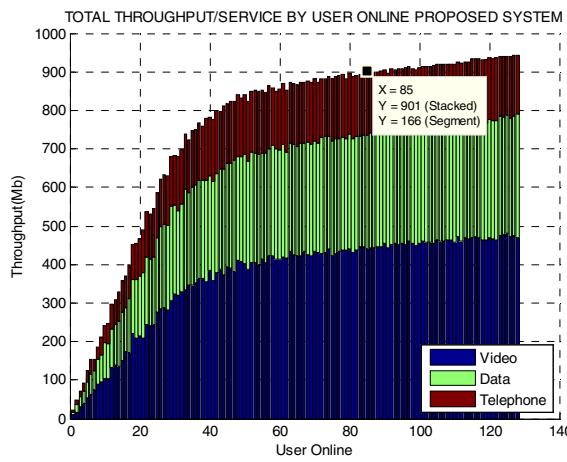


Fig. 9. Total throughput per service at overload condition in Proposed PON system

As shown from the results of the comparison between current system and proposed system, if we focus on maintaining throughput for video needs that do require a higher throughput than the others because the simulation uses various types of user and vary of the bandwidth allocated to the respective ONUs, so that the advantages of the system that we provide, first is to distinguish the type of users in need to consume service will help reduce the waste of bandwidth allocation early, so for users that only need to consume a voice / telephone will not be equated with the type of user who needs higher in bandwidth allocation, it is to increase the efficiency of bandwidth for the needs of other users, and then second when there is congestion by using the proposed system, to keep the scale that has been set, it will be helpful in determining the service which should be a priority when the high traffic demand from the user.

## V. CONCLUSION

This research has modified current burst methods to scheduling distribution SC on system OFDM from OLT to ONU to assure the user individual fairness services, by concerning with the amount of throughput required by each type of services. Proposed methods scaling SC customize services required by each user and distribute it by scheduling SC as the allocation.

From all simulation result, some conclusions can be derived. In the normal condition in both methods had the same result, each users throughput needs are met. In congestion condition, Bandwidth efficiency being seen by using the system proposed within a margin of 60% gain for maximum user online using random bandwidth allocation in ONU before it reaches congestion point. And also in congestion condition, system proposed still maintain the video service for HD Quality TV up to 125 users, better than current system that only maintain at 75 users online at the same time.

There are issues that may being contradictory application possibilities, such an additional more complicated process lead the possibility of improving the performance becomes more severe, and the development of new release applications led to the introduction services pattern in layer 1 becomes less accurate, which might need further analysis.

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