

Peris: A Novel Dynamic Bandwidth Allocation (DBA) Method with Second-Price Auction in Next Generation Military Networks Based on EPON Technology

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Abstract—In the foreseeable future, networks of access devices that can cooperate and effectively communicate with military backbone infrastructure will significantly influence and simplify military operations. As one of the promising solutions for developing next generation military networks, Ethernet Passive Optical Network (EPON) has received great attention from both industry and academia in recent years. Based on the EPON technology, bandwidth constraint is a critical issue in military communication. In this paper we propose Peris, a novel dynamic bandwidth allocation method with second price auction in next generation military networks based on EPON technology. In this new method, the OLT (similar to the leaders) is responsible for the auction management which effectively and fairly responds to the bandwidth requests of the users through their own ONUs and allocates the winners the amount of requested available bandwidth. Simulation results show that comparing Peris with IPACT, regarding QoS parameters such as packet loss ratio, line utilization and throughput, it has better performance.

Keywords- Next Generation Military Network, Ethernet Passive Optical Network (EPON), Bandwidth Allocation, Second-Price Auction.

I. INTRODUCTION

Recent advances in information technology have made the implementation of next generation military networks a reality. In the foreseeable future, networks of access devices that can cooperate and effectively communicate with military backbone infrastructure will significantly influence and simplify military operations [1]. People who are much dependent on their technical devices will be able to move to a level where a simple device will allow them to not only communicate with everyone and everywhere as well

as giving access to the information stored miles away from their location. Moreover, transmission of multimedia and ordinary files could be found invaluable in the battlefields. Therefore, the quality of service of military information send/recieve should be guaranteed to successfully perform military operations in the battlefield [2].

As one of the promising solutions for developing next generation military network, Ethernet Passive Optical Network (EPON) has received great attention from

both industry and academia in recent years. Development of fiber optic technologies have provided appropriate infrastructure for end users access to the service provider centers in network centric warfare environment. A subscriber can access military networks which cover the “last mile” communication network areas. Based on the EPON technology, bandwidth constraint is a critical issue in military communication. The recognition of bandwidth bottleneck is important not only for research reliability, but also for the successful implementation of military networks that will be designed for the survival of communications and keeping the next generation military network active on the battlefield [3].

In this paper we propose Peris, novel dynamic bandwidth allocation method with second price auction [4] in next generation military networks based on EPON technology.

The rest of this paper is organized as follows. In section 2, we will shortly introduce some important DBA methods in next generation military network based on EPON technology. Section 3, covers Peris method in detail. Section 4, presents simulation results and discussion. Finally conclusion will be in section 5.

II. RELATED WORK

A. Next Generation Military Networks

The next generation military networks are designed based on a 4-layers hierarchical structure, including platoon, company, battalion, and brigade (Fig. 1). Each of these layers is comprised of a leader and several members. The leader controls the members and establishes a military QoS with members in the same layer. At the same time, it acts as a member in a higher layer and is being controlled by the leader of that higher layer. By this hierarchical member-leader relationship, the multi-layers are combined in an integrated architecture.

The allocation of bandwidth and the efficient time management for sending the members-requested frames are two essential issues that the Next Generation Military networks are facing with, in order to prevent the data interference and queuing up the members at any time [5].

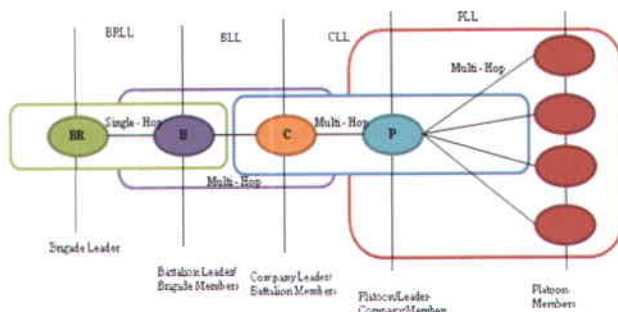


Fig. 1: Next generation military network architecture

In order to establish the next generation military networks based on the 4-layers architecture, various methods have been suggested so far which could operate on wired or wireless platforms. One of the major technologies on the wired platform is the EPON technology (Fig. 2) [6]. EPON is a network that consists of an OLT, as an operating centre, and several ONUs, which are the users whose requests are going to be dealt with. In this network architecture, the downstream line from the OLT to the ONUs is a point to multipoint network and the upstream line from ONUs to the OLT is a multipoint to point network, where there is a channel shared between the ONUs for sending the frames based on the MAC layers. Similarly, in designing the next generation military wired networks, one can design the leaders based on the OLT concept and the members based on the ONUs. The overall advantages of this new approach are including the higher flexibility, higher bandwidth allocation as well as a reduced cost to network establishment [7].

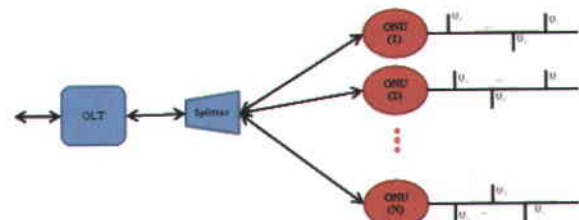


Fig. 2: EPON's architecture

B. Bandwidth Allocation Methods

Bandwidth is known as one of the most important QoS parameters in next generation military networks based on EPON technology [8]. To allocate bandwidth to each network unit, the optical line's terminal needs to provide some method based on the received bandwidth demands of optical network units and some allocation policies or service level agreements. Currently, various methods are recommended which can be classified into two general types: static bandwidth allocation and dynamic bandwidth allocation methods [9].

1. Static Bandwidth Allocation Methods

Each ONU is allocated a time slot with a fixed length which does not require bandwidth negotiation and is due to the bursting nature of the network traffic. This, however, may result in a situation in which some timeslots are overflowed even under very light load and causing packets being delayed for several timeslots while other timeslots are not fully used even under very heavy traffic load and, therefore, leading to an underutilized upstream bandwidth. Thus, the static allocation is not preferred in many scenarios [10].

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2. Dynamic Bandwidth Allocation Methods

To increase the bandwidth utilization, the OLT must dynamically allocate a variable timeslot to each ONU based on the instantaneous bandwidth requests of the ONUs. Given that QoS is the main concern in EPONs, thus these methods are classified into DBA without QoS support such as IPACT, IPACT GE, Estimation-based DBA and IPACT with SARF and DBA with QoS support such as FSD-SLA , LSTP, and DBAM [11-15].

III. THE PERIS METHOD

The proposed a novel dynamic bandwidth allocation method, Peris, is based on the auction theory and is capable of implementing in the Next Generation Military networks based on EPON. In this new method, the OLT (similar to the leaders) is responsible for the auction management which responds to the bandwidth requests of the users through their own ONUs according to the following steps. The members in the next generation military networks are assumed as the users related to the ONUs. The OLT responds in an effective and fair manner, relative to the priority of users and the maximum time for which they are waiting to receive their bandwidth. Overall, the major steps in this auction-based method are listed as follows and are being shown in Fig. 3.

First step: Announcing the auction by the OLT for the allocation of users-requested bandwidth and submitting the initial conditions to the users through the ONUs.

Second step: Analyzing the initial auction conditions by the users and announcing the bandwidth requests' parameters through the ONUs to the OLT. These parameters are the maximum waiting time of an ONU to receive a service, the requested bandwidth from users, and the priority of users.

Third step: Evaluating the received requests from the ONUs and calculate the bid value of each user followed by selecting the winners and producing a sub-list from the received list of each of the ONU's users.

Fourth step: Allocation of the requested bandwidth to the winner users through their ONUs and supervision of the bandwidth under use.

Fifth step: Repeating the process from the first step.

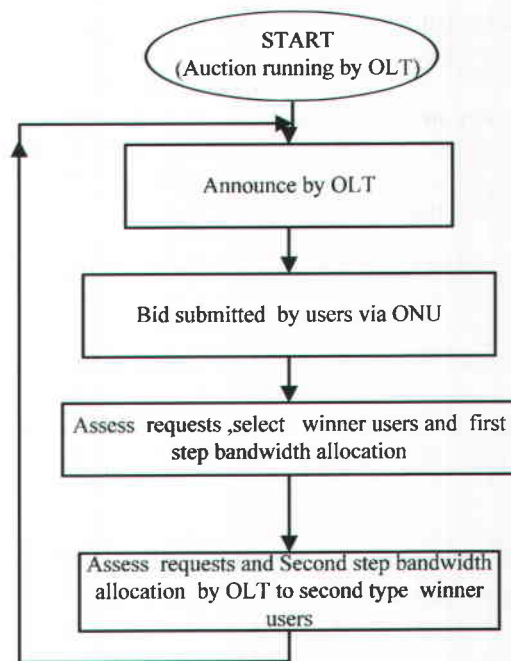


Fig. 3: Overall design of the proposed Peris method

The above algorithm and the proposed Peris model are discussed in more details here. In the first step, OLT submits the conditions of auction to all the users, including the allocated time slot to each user in order to send their requests through the ONUs, the maximum bandwidth available from the OLT, and the time required for the OLT to respond to the received requests.

In the next step, the users send their requests to the OLT through their ONUs as parametric bid values after evaluating the conditions of the auction. The relationship between various parameters and the final bid value is demonstrated in equations (1), (2) and (3).

$$Bid_j^i(t) = \theta(\pi_j^{ONU_i}(t), BW_{ONU_i}^{Req_j}(t)) \quad (1)$$

In equation 1, $\pi_j^{ONU_i}$ is the cost function that the $user_j$ announces for the requested bandwidth and the $BW_{ONU_i}^{Req_j}$ is the requested bandwidth of $user_j$ at the time t .

$$\pi_j^{ONU_i}(t) = \frac{Pr_j^{ONU_i}(t)}{BW_{ONU_i}^{Req_j}(t) * D_{User_j}^{ONU_i}(t)} \quad (2)$$

Equation (2) shows the value of $\pi_j^{ONU_i}$, where the $Pr_j^{ONU_i}$ is the priority of the j^{th} user who has requested a bandwidth through the ONU_i . In order to



simplify the computations and overhead reduction, the priority of users is determined based on the type of their requested traffic which provides a fair and equal situation for all users.

$$Pr_j^{ONU_i}(t) = \frac{\sum_{j=1}^k [TTP_j^{user}(t) * N_j^{TRT}(t)]}{j} \quad (3)$$

Equation (3) demonstrates the priority of $user_j$, where TTP_j^{user} is the priority of the j^{th} user dependent on the type of requested traffic and N_j^{TRT} is the number of $user_j$ request from this traffic. In Peris, the user's priority is being specified according to the requested traffic types from the users that have been sent through the ONU_i . Moreover, in this method for a more suitable simulation, three levels of traffic priority have been considered which are high, medium, and low. One of the major advantages of this method is that the more traffic priority levels will not affect the function of the algorithm and, therefore, different priority levels can be maintained. Furthermore, all of the ONUs are given a similar level of priority. Table 1 illustrates these priority levels.

Table 1: Priority of users' traffic

Priority of Traffic	Value
High	3
Medium	2
Low	1

Additionally, in Equation (2) $BW_{ONU_i}^{Req_j}$ is the maximum requested bandwidth that has been announced by the $user_j$ dependent on their type usage. In Peris method, it has been assumed that the ONU_i buffer has no limitation for receiving the submitted requests from the users. Equation (4) shows the requested bandwidth of $user_j$

$$BW_{ONU_i}^{Req_j}(t) = \sum_{j=1}^m UB_j^{Req}(t) \quad (4)$$

Where

$$UB_j^{Req}(t) = m_{jk}^{Frame} * L_{jk}^{Frame} \quad (5)$$

In equation (5) the m_{jk}^{Frame} shows the number of requested frames from the $user_j$ within the traffic type k and L_{jk}^{Frame} is the length of the frames sent by the $user_j$ from this type of traffic. Finally, in equation (2), the $D_{user_j}^{ONU_i}(t)$ value is the maximum delay that $user_j$ can expect to receive the requested service.

In third step of this proposed method, OLT evaluates the auction participation requests received from the users. This evaluation is mediated by initially confirming whether there is at least one user has submitted its request through it's being ONU or not. If the above was confirmed, a list of all the users who have requested to participate in the auction is generated with this assumption that they are currently idle. The bid values for the users are then calculated and examined with the second price auction theory. At this stage, K users are selected as the winners of the auction and the bandwidth is then allocated through their ONUs with the only condition that the total requested bandwidth of the winners is less-than or equal to the maximum available bandwidth offered by the OLT. This has been further illustrated in equation (6).

$$ABW_{OLT}(t) \geq \sum_{w=1}^k BW_{User_w}^{Req}(t) \quad (6)$$

In equation (6), $ABW_{OLT}(t)$ is the bandwidth available to the OLT in time t and $BW_{User_w}^{Req}(t)$ is the requested bandwidth of $user_w$ in time t.

Furthermore, in order to increase the efficiency of line utilization and robustness if there was more bandwidth available than the total allocated bandwidth to the winners, there would be another round of auction between the users who could not win earlier and have sent new requests. The remaining bandwidth is then allocated to the winners of the second auction. However, there could be no winners in the second round.

The fourth step begins after the winners of the second round of auction received their requested bandwidth. This step is called service time level in Peris, where OLT stands by until a part of earlier allocated bandwidth becomes free and can be offered by the OLT in another round of auctioning. The minimum level of bandwidth required for reinitiating the auction is defined as the bandwidth threshold shown in equation (7).



$$A_{threshold} = \begin{cases} 1 & ABW_{OLT}(t) \geq \frac{TBW_{OLT}^{Allocated}(t-1)}{3} \\ 0 & \text{Otherwise} \end{cases} \quad (7)$$

In equation (7), $A_{threshold}$ is a Boolean value that defines if auction reinitiating would be held and $TBW_{OLT}^{Allocated}(t-1)$ is the total allocated bandwidth to the users in the previous round of auction. Moreover, to increase the success rate for the users who haven't received a bandwidth yet and preventing starvation, the delay tolerance field in their bid values gets updated. The new delay tolerance value of $user_j$ from ONU_i is being demonstrated in equation (8).

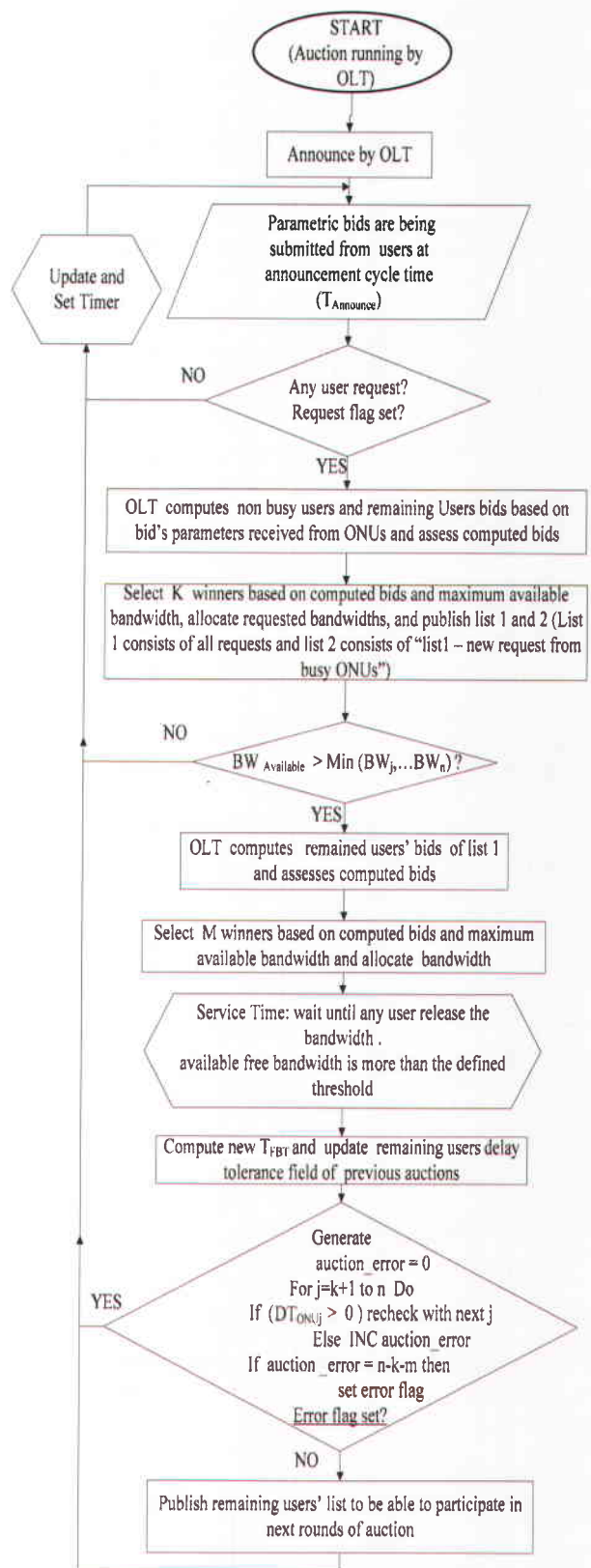
$$D_{user_j}^{ONU_i}(t) = D_{user_j}^{ONU_i}(t-1) - AT_{OLT} - BW_{released-time} \quad (8)$$

In equation (8), AT_{OLT} is the time difference between the auction start time and the bandwidth allocation time by the OLT, and $BW_{released-time}$ is the time length required for the threshold bandwidth to become available for a new round of auction. If the new delay tolerance values were greater than zero, a list of new users with bandwidth requests would be generated and recycled in a new round of auction.

Finally, in the fifth stage, a new round of auction begins to evaluate the remaining requests from the last round as well as new requests received. To start this stage, the OLT should stand by for a little while and then reinitiate the auction. To achieve this, a default timer has been designed which value is updated after the first round of auction. In Peris, the timer value is a time average between each of the auction steps, until the bandwidth threshold becomes available (equation (9)). In addition to the average values, median or mode parameters could also be used.

$$Timer_{set}^{value}(t) = \frac{t_{AA}^0 + t_{AA}^1 + \dots + t_{AA}^k}{k+1} = \frac{\sum_{j=0}^k t_{AA}^j}{k+1} \quad (9)$$

In equation (9), t_{AA}^j is the time difference between the two auctions at time j . Fig. 4 shows the execution process and related pseudo code for new proposed method, Peris.



(A)



```

Start of Peris Method
:STEP I
  Run (Auction process by OLT) /*Auction process running by
  OLT*/
  Send(announce signal from OLT to users via ONUs)
:STEP II
  For I = 1 to n Do
    If (Useri has a Req.?) Then
      Submit (Parametric bid) /*Send parametric bid from users to
      OLT by ONU*/
    Else
      Send (Auction_out_msg)/*send exit message from
      auction and wait until receive new Req.*/
    End If
  End For
:STEP III
  For j = 1 to n Do
    Bid-Computation (Non busy userj)
  End For
  For L = 1 to n Do
    Select (winners) /*select k winner by OLT based on Second
    Price Sealed Bid Auction*/
  End For
  Publish List 1. /*list 1 consists of all user's Request*/
  Publish List 2. /*list 2 consists of (List 1.)-(K winner)-(new
  Request From Busy users)*/
  If (ABWOLT > Min(BW1,...,BWn))
  Then
    {
      For j = 1 to m Do
        Bid-Computation(Users from list 2)
      End For
      For j = 1 to m Do
        Select (winners)
      End For
    }
  Else
    Send (Auction_out_msg)
  End If
:STEP IV
  Until (ABWOLT > BWTHRESHOLD) Do
    Wait (Service-Time)
  End Until
  For k = 1 to j Do
    Compute (new Delay tolerance for users from list 2)
  End For
  Auction_error=0
  For j=1 to (n-k-m) Do
    If (Delay tolerance (Useri) >0)
  Then
    Generate List 3. /*list 3 consists of (remaining
    users from previous auction)+(new Req
    from users)*/
  Else
    INC auction_error
  End If
  If (auction_error=n-k-m)
  Then
    Publish List 3. /*list 3 for next round of
    auction*/
  Else
    Send (Auction_out_Msg)
  End If
  End For
:STEP V
  Goto (STEP I)
End of Peris Method
    
```

(B)

Fig. 4: Execution process (A) and related pseudo code (B) in proposed method, Peris.

IV. SIMULATION RESULTS

In order to compare the performance of Peris method with other dynamic bandwidth allocation methods in the next generation military networks based on EPON, we have designed a C++-based DBA simulator. In the simulation process, a multipoint to point network based on the EPON architecture (Fig. 2) have been used. Table 2 shows the relevant simulation parameters.

Table 2. Simulation parameters

Parameters	Value
Number of ONUs	16
Bit Rate	5 to 57.5 MBit/s
Two way Delay Fiber	200 μs
Processing Time	35 μs
Packet Size	15000 Byte (30 Packets)
Ethernet Overhead	38 Byte
Request Message Size	570 Bit
Upstream Bandwidth	1 GBit/s
Max Transition Window	10 Packets
Guard Time	5 μs
Max Cycling Time	2 ms
Buffer Capacity	10 MByte
Traffic Type	Poisson distribution

In this section, Peris, the proposed Peris method is being compared to IPACT regarding simulation parameters specified in table 2. The QoS parameters analyzed in this comparison are include delay, throughput rate, packet loss ratio, and line utilization. Fig. 5 shows the comparison of average delay in Peris and IPACT. There is a longer delay in Peris at the first step of the auction due to the calculation of requested bandwidth and sending parametric bid values. In the remaining course of auction, the behavior of Peris is similar to IPACT and the calculation times are shorter as a result of decline in the number of requests. However, at the end of the third step when the number of requests is rising again, the delay parameter also goes up accordingly.

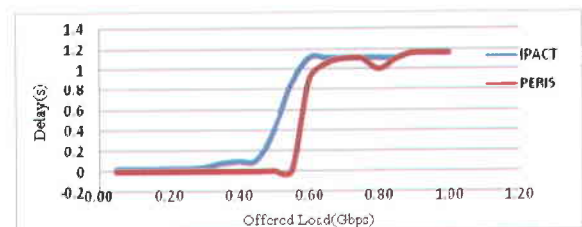


Fig. 5: Comparison of average delay in Peris and IPACT

Fig. 6 illustrates the percentage average of packet loss ratio in Peris and IPACT. Peris demonstrates a lower level of packet loss ratio since all the users who submit a greater bid value can win the auction and receive a bandwidth relevant to their bid values and transfer their packets. Furthermore, in Peris based on different request lists generated in the auction, all the users are going to receive their requested bandwidth



before the end of their waiting time for receiving the service which, in turn, will reduce the packet loss ratio to a minimum level. As it can be noticed in Fig. 6, the packet loss ratio is significantly higher in IPACT since in this method based on the round robin concept, the ONUs are only permitted to send packets without any limitations at a specified time slot. Thus, many packets are lost due to over-riding the time limit of receiving the service.



Fig. 6: Comparison of packet loss ratio in Peris and IPACT.

Fig.7 demonstrates the throughput rate of the packets in the compared methods. As it can be observed, in the IPACT method since a stable period of time is given to each ONU according to its buffer volume, the throughput rate shows a similar behavior against the increased traffic load. Therefore, in this method, the throughput rate is lower as a result of equality between the allocated bandwidth to the ONUs. On the contrary, the proposed method demonstrates a better throughput rate because the bandwidth is allocated in a more robust manner based on the Second Price Auction Theory where the designed conditions allow all the users with requests to participate in the auction that is comprised of different steps. This observed improvement in the throughput rate is due to the bandwidth allocation to all the users through their ONUs which is shown to be a better approach in various types of traffic.

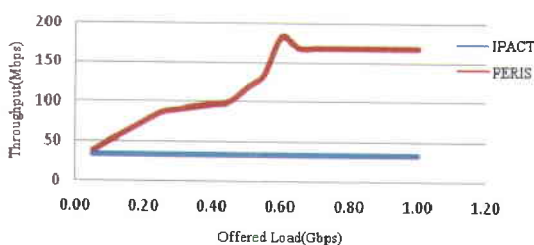


Fig. 7: Comparison of throughput in Peris and IPACT

Finally, Fig. 8 illustrates the percentage of line utilization in Peris and IPACT. As it can be observed in the figure, Peris confers a better line utilization because all the packets are submitted at different time points and, therefore, the line is utilized in the best possible way. Moreover, there is no time limitation for sending the packets, although line remains unused only at the beginning of the cycle to allow the users to participate in the auction which will subsequently result in an increase in the submission delay. At any other time point, the line is fully utilized. In IPACT

the line utilization rate is lower despite the fact that each ONU is allocated an unlimited period of time in an alternative manner. In IPACT, the ONU transmits the data in the allocated period of time according to the data volume and, therefore, with lower data volumes the line utilization would also be reduced.

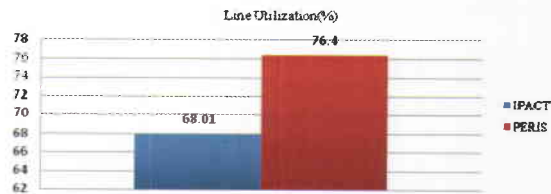


Fig. 8: Comparison of line utilization in Peris and IPACT.

V. CONCLUSION

Regarding the importance of dynamic bandwidth allocation in next generation military access networks based on EPON technology, in this paper, we have proposed Peris, a novel auction-based DBA method. In Peris, OLT (leader) manages the auction and ONUs (members) send their requests. Simulation results show that Peris experience more delay but regarding other QoS parameters such as packet loss ratio, line utilization and throughput, it has better performance. This better performance lets more users to request services in military environments and thus results better leadership and control in battlefields. Regarding the extension of research in this area, in future it would be able to open new horizons by utilizing heuristics methods such as Genetic algorithm, cellular automata, and neural networks, beside proposed method. Moreover, Peris proposed method could be used and evaluated in wireless infrastructures such as Wi-Fi, and WiMax.

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