

TR-402

Functional Model for PON Abstraction Interface

Issue: 1.0
Issue Date: October 2018

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Issue History

Issue Number	Approval Date	Publication Date	Issue Editor	Changes
1.0	4 October 2018	4 October 2018	Kota Asaka, NTT	Original

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Executive Summary

For reduced cost, agile service adaptation in next-generation optical access, a new system architecture, based on SDN/NFV technologies, is required by operators. The most promising approach is to disaggregate PON functions into functional modules with open interfaces. The BBF's new PON Abstraction Interface for Time-Critical Applications project develops the architecture further by specifying a PON abstraction interface for time-critical processing functions, such as Dynamic Bandwidth Assignment (DBA).

This Technical Report defines the functional modules and interfaces need to disaggregate a PON function that needs time-critical processing. The reader should refer to WT-403 "PON abstraction interface specifications" for detailed interface specification definitions.

1 Purpose and Scope

1.1 Purpose

The purpose of this Technical Report is to specify the high level functional model, use cases, API requirements for time-critical PON abstraction interfaces that WT-403 interface definition supports.

1.2 Issues addressed

There are two aspects of issues being addressed from the operator's point of view. Firstly, the operators need to provide sustainable broadband services for residential users on widely deployed fiber access networks. To keep the services cost-effectively, operators need to update the PON functions, which include a function that needs time-critical processing, by using software update. This enables operators NOT to rebuild an OLT from the preliminary stage of development (e.g. re-make of PON chip), which requires a large amount of investment.

The second aspect is that the operators wish to provide a large variety of services on access network, such as broadband service for business users and mobile front haul for 5G. This should be a new business opportunity not only for operators but also for vendors, since a disaggregated OLT based on the proposal can be applicable to 5G mobile front haul by replacing a low-latency Dynamic Bandwidth Assignment software.

1.3 Scope

This Technical Report defines the PON abstraction interface and use cases for time-critical applications such as Dynamic Bandwidth Assignment (DBA) and Dynamic Wavelength Assignment (DWA). This Technical Report defines a new API that interfaces open source solution. This Technical Report applies to ITU-T PON technologies. IEEE PON technology is for future study.

2 References and Terminology

2.1 Conventions

In this Technical Report, several words are used to signify the requirements of the specification. These words are always capitalized. More information can be found in RFC 2119.

MUST	This word, or the term “REQUIRED”, means that the definition is an absolute requirement of the specification.
MUST NOT	This phrase means that the definition is an absolute prohibition of the specification.
SHOULD	This word, or the term “RECOMMENDED”, means that there could exist valid reasons in particular circumstances to ignore this item, but the full implications need to be understood and carefully weighed before choosing a different course.
SHOULD NOT	This phrase, or the phrase "NOT RECOMMENDED" means that there could exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications need to be understood and the case carefully weighed before implementing any behavior described with this label.
MAY	This word, or the term “OPTIONAL”, means that this item is one of an allowed set of alternatives. An implementation that does not include this option MUST be prepared to inter-operate with another implementation that does include the option.

2.2 References

The following references are of relevance to this Technical Report. At the time of publication, the editions indicated were valid. All references are subject to revision; users of this Technical Report are therefore encouraged to investigate the possibility of applying the most recent edition of the references listed below.

A list of currently valid Broadband Forum Technical Reports is published at www.broadband-forum.org.

Document	Title	Source	Year
[1] RFC 2119	<i>Key words for use in RFCs to Indicate Requirement Levels</i>	IETF	1997
[2] G. 987.3	<i>10-Gigabit-capable passive optical networks (XG-PON): Transmission convergence (TC) layer specification</i>	ITU-T	2014
[3] G.989.3	<i>40-Gigabit-capable passive optical networks (NG-PON2) transmission convergence (TC) layer specification</i>	ITU-T	2016

	Amd.1	<i>PON2): Transmission convergence layer specification Amendment 1</i>		
[4]	G. supplement 51	<i>Passive optical network protection considerations</i>	ITU-T	2016
[5]	TR38.801	<i>Study on new radio access technology: Radio access architecture and interfaces (Release 14)</i>	3GPP	2017
[6]	TR352i1	<i>Multi-wavelength PON Inter-Channel-Termination Protocol (ICTP) Specification</i>	BBF	2017
[7]	1588-2008	<i>Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems</i>	IEEE	2008
[8]	G.8271.1	<i>Network limits for time synchronization in packet networks</i>	ITU-T	2013
[9]	G.8275.1	<i>Precision time protocol telecom profile for phase/time synchronization with full timing support from the network</i>	ITU-T	2016
[10]	G.8275.2	<i>Precision time protocol telecom profile for time/phase synchronization with partial timing support from the network</i>	ITU-T	2016
[11]	G.8273.2	<i>Timing characteristics of telecom boundary clocks and telecom time slave clocks</i>	ITU-T	2017
[12]	G.703	<i>Physical/electrical characteristics of hierarchical digital interfaces</i>	ITU-T	2016
[13]	G.8275	<i>Architecture and requirements for packet-based time and phase distribution</i>	ITU-T	2013
[14]	G.8265.1	<i>Precision time protocol telecom profile for frequency synchronization</i>	ITU-T	2014

2.3 Definitions

The following terminology is used throughout this Technical Report.

Time-critical application	The time-critical application is a function in optical access system (e.g. PON), which requires high-speed processing, such as DBA, and DWA.
PON abstraction interface	The PON abstraction interface is an API that provides flexibility of time-critical application. The time-critical application having algorithm dependent function can be disaggregated to the common behavior part as engine, and the differentiation part as algorithm. The interface between two parts are called the PON abstraction interface, and specified as an API. By using APIs, differentiation/flexibility of time-critical applications can be achieved by updating/replacing algorithm part, which is a software component.

- Common engine** The common engine represents the lower side of the API, which offers the time critical functionalities for the algorithm part. The engine is typically assumed to be hardware inside OLT box. The algorithm part can be replaced with another one, where any algorithms can commonly utilize the engine.
- DBA cycle** The DBA cycle is a time period of DBA calculation where it is typically same in length as the total duration of the bandwidth assignment. For example, when the DBA cycle is 1ms, DBA has to calculate for 1ms-long assignment of upstream transmission from ONUs. That assignment may include multiple bursts and multiple BWmaps for each ONU according to the length of the DBA cycle. Because each assignment is 1ms-long, the calculation should be repeatedly performed at least once in 1ms in order to avoid blank period.

2.4 Abbreviations

This Technical Report uses the following abbreviations:

API	Application Programming Interface
App	Application
ANI	Access Network Interface
CPU	Central Processing Unit
CT	Channel Termination
CU	Central Unit
DB	Decrease Buffer Occupancy
DBA	Dynamic Bandwidth Assignment
DU	Distributed Unit
DWA	Dynamic Wavelength Assignment
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IPTV	Internet Protocol Television
ITU-T	International Telecommunication Union – Telecommunication Standardization Bureau
LTE	Long Term Evolution
ONU	Optical Network Unit
OLT	Optical Line Termination
PON	Passive Optical Network
OSS/BSS	Operations Support System/Business Support System
QoS	Quality of Service
SR-DBA	Status-reporting Dynamic Bandwidth Assignment
SLA	Service Level Agreement
SNI	Service Node Interface

TR	Technical Report
UE	User Equipment
WA	Work Area
WMS	Wavelength Mobility Synchronization
WMR	Wavelength Mobility Request
WT	Working Text

3 Technical Report Impact

3.1 Energy Efficiency

This Technical Report has no impact on Energy Efficiency since it is assumed that time-critical applications reside in an OLT.

3.2 IPv6

This Technical Report has no impact on IPv6.

3.3 Security

This Technical Report has no impact on Security.

3.4 Privacy

This Technical Report has no impact on Privacy.

4 Disaggregation policy for time-critical applications

4.1 Algorithm disaggregation and interface

To make time-critical functions flexible, an appropriate software API to modify or to extend functions is required. This is achieved by disaggregating algorithms. In addition, the interface between algorithm part and common engine should be specified as a common API, as shown in Figure 4-1. In order to reduce dependency on hardware or on algorithm, the data to exchange between algorithm part and common engine should be raw data which are not processed at common engine.

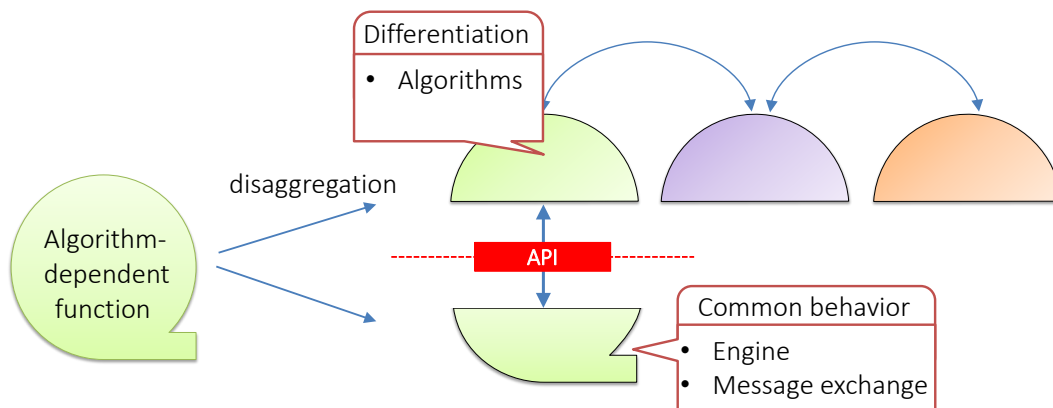


Figure 4-1 Schematic image of algorithm disaggregation

Supplementary information on a disaggregated DBA application, which is one of the time-critical applications and virtualization of DBA for multi-tenancy purpose, is explained in Appendices of this Technical Report.

4.2 Example hardware configurations for algorithm disaggregation

In this document, disaggregation of algorithm from common engine does not directly express the physical separation among different hardware boxes. An example hardware configuration is illustrated in Figure 4-2, where both of algorithm and engine can be located in the same OLT box. In this example, the algorithm part is running on a CPU as a software component in one of the OLT line cards. The engine part is located in the PON hardware which is assumed to mainly process data at data plane at wire rate. The behavior of the engine is controlled by the algorithm running on the CPU which is connected to PON hardware. Although representative PON hardware would be ASIC (application-specific integrated circuit) or FPGA (field-programmable gate array) considering the required speed at wire rate, this document does not specify actual hardware type.

In Figure 4-2, one engine in one PON hardware covers several physical PON ports. Another example configuration in Figure 4-3 shows one-on-one relationship among CPU, PON hardware, and physical PON port. This also indicates that either multiple algorithms or multiple engines can be inside in one line card. The other example configuration in Figure 4-4 shows different numerical

relationship between CPU and PON hardware, which indicates that one algorithm can control multiple engines.

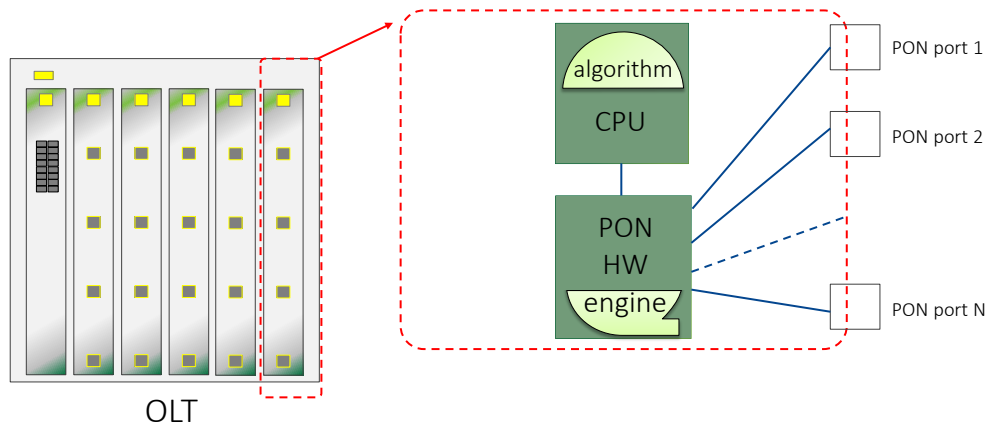


Figure 4-2 Example hardware configuration with algorithm and engine

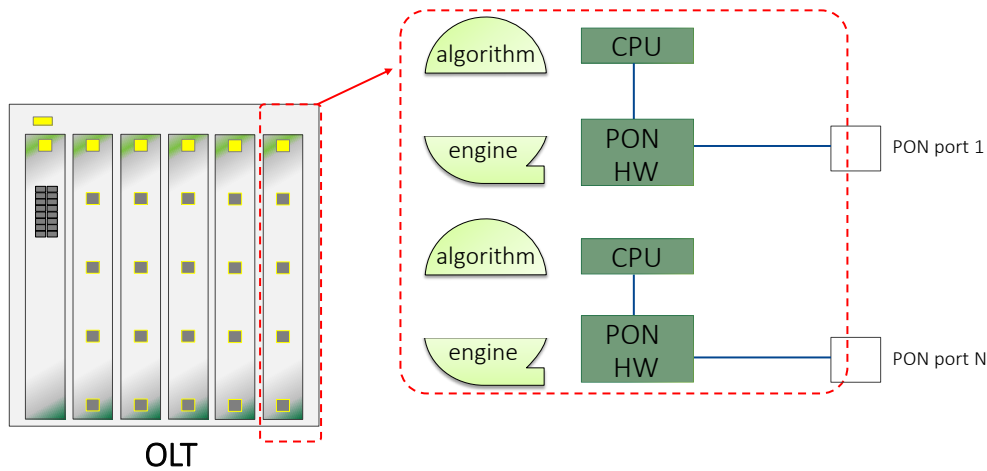


Figure 4-3 Example hardware configuration with multiple algorithms and engines

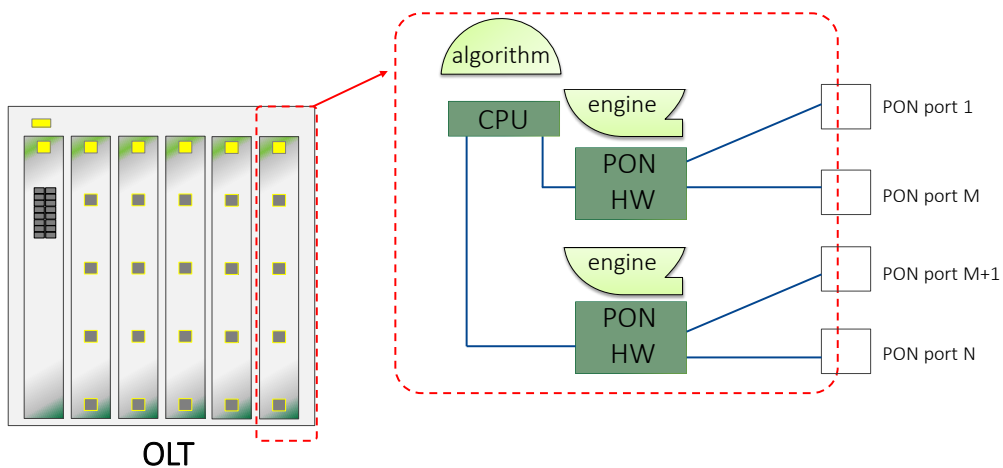


Figure 4-4 Another example with different ratio between algorithm and engines

5 Use cases

This section discusses the time critical use cases for DBA and DWA.

Dynamic bandwidth assignment (DBA) in PON is the process by which the OLT allocates upstream transmission opportunities to the traffic-bearing entities within the ONUs, based on the dynamic indication of their activity and their configured traffic contracts. DBA algorithm supports the configuration of the maximum bandwidth and does not currently address low latency. ITU is studying low latency algorithm. Any disaggregated DBA engine will need to add support for low latency.

5.1 DBA for service differentiation

A service provider studies how to differentiate its services from competitors. For communication services, there are several differentiating factors other than price, e.g. maximum bandwidth, assured bandwidth, or average throughput for the Internet. When all the service providers are offering similar services with same speed, a new service differentiation factor would be a key to service providers. In PON systems, QoS of upstream traffic is controlled by DBA. Therefore, DBA has a significant relationship to the service differentiation. Although typical parameters like maximum bandwidth are configurable as parameters, some of those needs dedicated algorithm DBA. For example, a low latency service can be achieved by a low latency DBA algorithm. It also means that algorithm replacement of DBA enables service differentiation especially when the customer requires low latency. Even if off-the-shelf DBA algorithm, which is initially implemented in the OLT, is not designed for low latency but for high bandwidth efficiency, service provider would be able to offer what the customers need by replacing the DBA algorithm with alternative one.

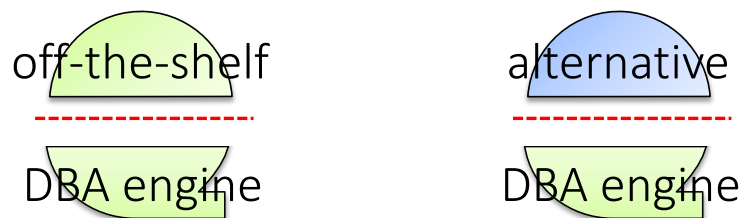


Figure 5-1 DBA for service differentiation

5.1.1 DBA overview

The sub clause explains a basic knowledge of the status-reporting (SR) DBA mechanism in order to provide the better understanding of DBA use cases in non-time-critical and time-critical cases.

Figure 5-2 shows a typical SR-DBA. The upstream data arrived at ONU is buffered until its transmission to ANI (access network interface) is granted in TDM-based PON systems. In SR-DBA, ONU reports its queuing size to OLT as a request for upstream transmission. Then DBA at the OLT side calculates the appropriate bandwidth for each ONU. For ITU-T PONs, the grant for the upstream transmission is assigned by the form of BWmap which includes *StartTime* and *GrantSize*. These parameters express when to start the transmission and how long it should be. Although there

is a room for extending the upstream burst to cross the border of the next 125 μs period, DBA is basically expected to assign how to share the 125 μs with ONUs.

Because BWmap does not need to include all of the allocations for all of the ONUs, OLT may receive reports from a part of the ONUs in the PON branch. This also indicates that the calculation time of DBA does not always have to be less than BWmap cycle. It should be less than the time to collect the reports from all the ONUs, where it would require DBA to calculate multiple BWmaps. In either way, the key of the DBA is that the delay at the ONU for the upstream transmission largely depends on the time between when its request is generated and when the request is reflected as grant(s).

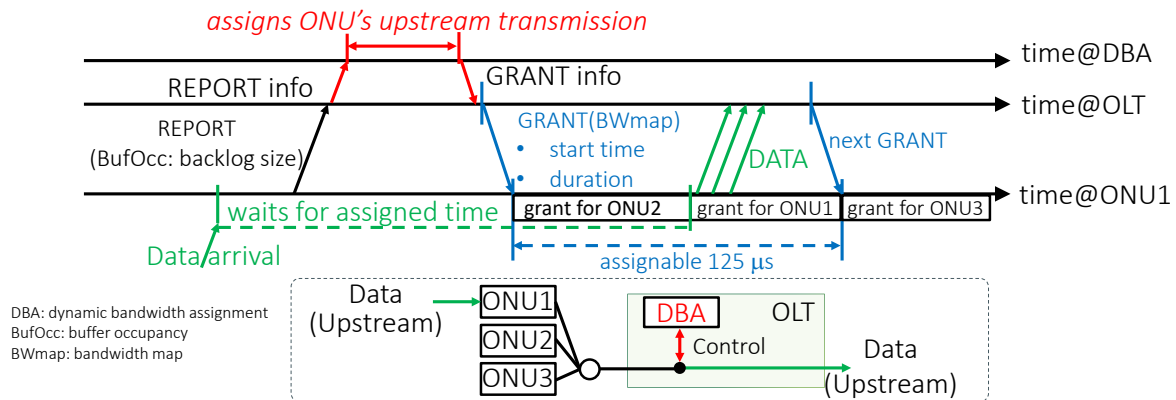


Figure 5-2 Status-Reporting DBA mechanism

As shown in Figure 5-2, the SR-DBA controls the upstream traffic as following.

1. Upstream data arrives at ONU and is buffered in ONU.
2. ONU reports its queuing (backlog) size to OLT as a request of upstream transmission.
3. OLT assigns each ONU's transmission (when and how long it should be) based on the collected reports.
 - In ITU-T PON standards, one BWmap can designate its transmission time for no further than 125 μs.
 - Therefore the BWmap should be sent from OLT to ONU every 125 μs.
 - On the other hand, its calculation how much bandwidth to allocate to different T-CONT can be accumulated (e.g. calculation for N x 125 μs).

5.1.2 Time constraint of DBA

When using DBA for time critical applications, processing delay shown in Figure 5-3 should be much less than DBA cycle (N x 125 us). If the processing delay is large relative to DBA cycle, the delay for the upstream data arrives at ONU would increase in 125 us unit.

Figure 5-3 shows the typical SR-DBA for ITU-T PONs. As described before, the QoS is largely depends on the time between when the request for upstream transmission is generated and when it is reflected. Because the opportunity of reflecting the scheduling calculation comes every 125 μs at the earliest, the DBA delay increases in the unit of 125 μs. If the opportunity for an ONU comes once in multiple BWmaps, the delay increases in the unit of the corresponding BWmaps. Therefore, the interface to tell CPU of report information and the one to designate grant information from CPU

are time-critical, even while the processing delay to calculate the schedule depends on the DBA algorithms.

As shown in Figure 5-3, the DBA as a TC application controls the upstream traffic as following.

1. Upstream data arrives at ONU1 and is buffered in ONU1.
2. ONU1 reports its queuing size to OLT as a request of upstream transmission.
3. CPU in OLT calculates ONUs' transmission (when and how long it should be) based on the collected reports.
4. OLT issues transmission grants for ONU1 and ONU2 as BWmap based on the calculated result in the CPU.
5. ONU1 actually transmit the buffered upstream data to OLT.

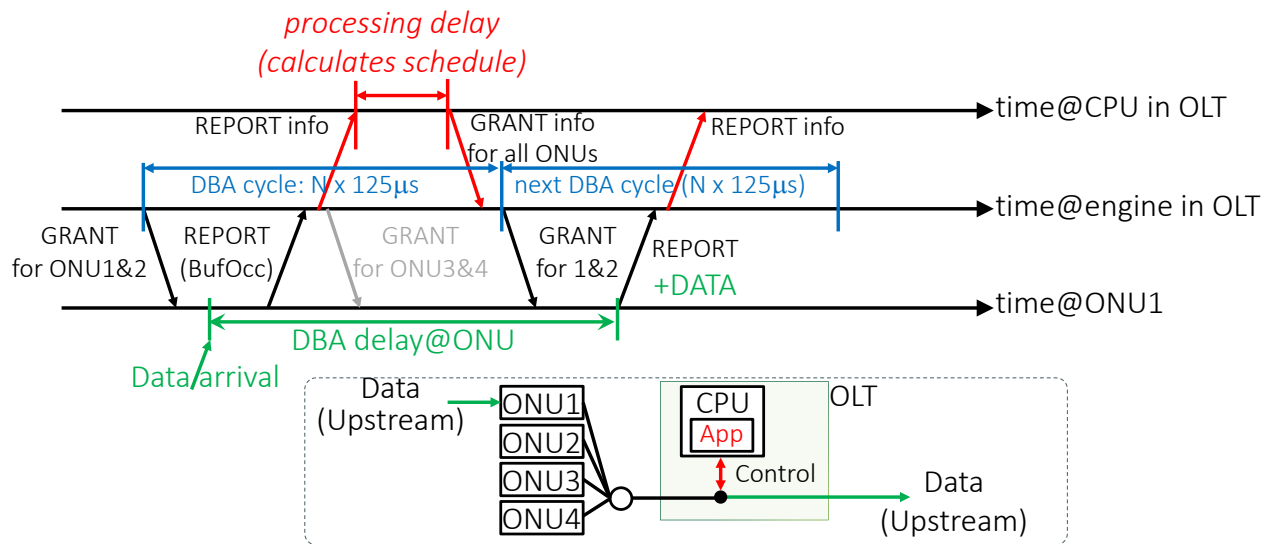


Figure 5-3 Time constraint of DBA

5.1.3 DBA for mobile front haul

For mobile front haul services, the summation of DBA delay and propagation delay should be shorter than 250 µs [1].

As shown in Figure 5-4, the low-latency DBA as a TC application for mobile front haul controls the upstream traffic as following. The use case assumes that OLT has an interface that receives scheduling information from external equipment. In this use case, OLT and BBU are built in an independent chassis, respectively.

1. UE1 sends a request for upstream transmission to BBU. This request is transferred by RRH, ONU1, and OLT.
2. BBU schedules the upstream transmission according to the requests from UEs.
3. BBU sends the calculated scheduling information to UE1 (Scheduling calculation at BBU is out of scope in WT-402).
4. OLT receives or snoops the scheduling information from BBU.

5. DBA calculates the time when the upstream data would arrive at ONU1 based on the scheduling information. DBA also calculates the duration how long the data arrival would continue. (The processing delay indicated in Figure 5-4 is for calculating or translating these time and duration from scheduling information.)
6. OLT issues grants using the result of DBA calculation.
7. UE1 sends the upstream data designated by the scheduling information from BBU.
8. ONU1 starts upstream transmission designated by the grants from OLT.
9. The delay for the upstream data to wait for in the ONU1 is expected short.

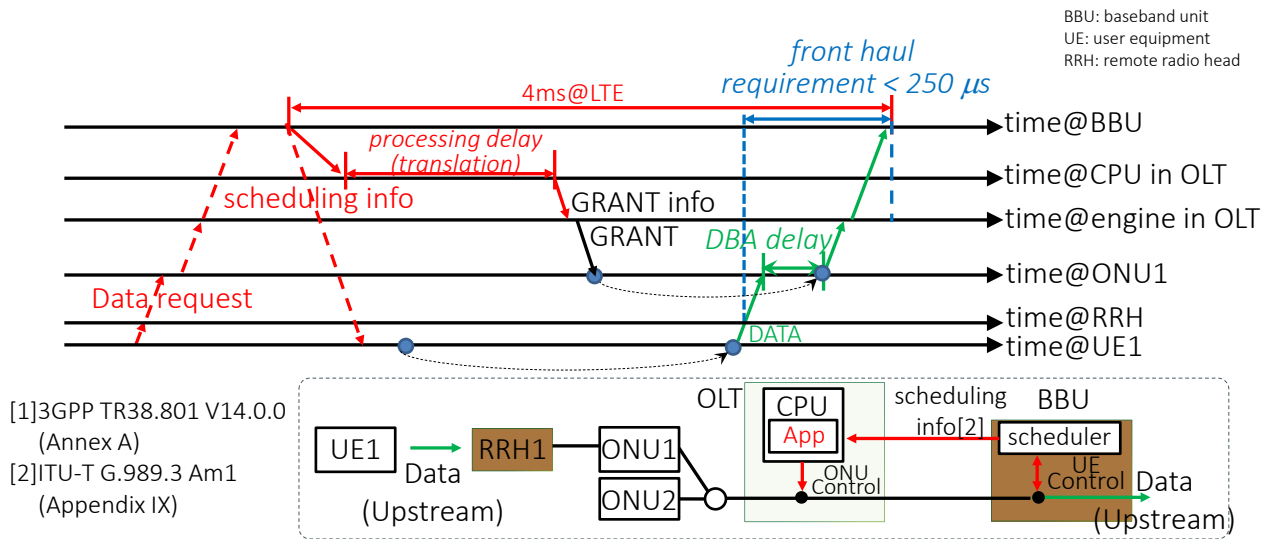


Figure 5-4 DBA for mobile front haul

6 Functional requirements of the APIs for time-critical applications

6.1 Low-latency DBA

Following PON functionalities are required as time-critical interface for the DBA use cases (R-1 and R-2 are time-critical interfaces for DBA use case described in Clause 5.1.2, and R-1 through R-4 are those described in Clause 5.1.3).

- [R-1] API MUST grant transmission (to construct BWmap) with precise time designation.
- [R-2] API MUST get status reports (to get BufOcc) with precise time designation.
- [R-3] API MUST read scheduling information sent from external system.
- [R-4] API MUST exchange information from PON to external system.

Low latency DBA requires tight control of the start/stop time of serial number, ranging and PLOAM transmission.

- [R-5] API or capability MUST start/stop (autonomous) serial number acquisition process.
- [R-6] API or capability MUST start/stop (autonomous) ranging process.
- [R-7] API or capability MUST start/stop (autonomous) PLOAM transmission.

7 APPENDIX A: Time clock tree for mobile DBA use case

This Appendix shows supplementary information on DBA for mobile front haul (Clause 5.1.3) in the main text of this Technical Report.

In Figure 7-1, it shows time-related functional parts for handling TC messagings inside the OLT; TC App, TC Platform and OS inside the CPU, and DBA uP inside the OLT chip. The time constraints would need to be guaranteed across these parts provided by each vendor.

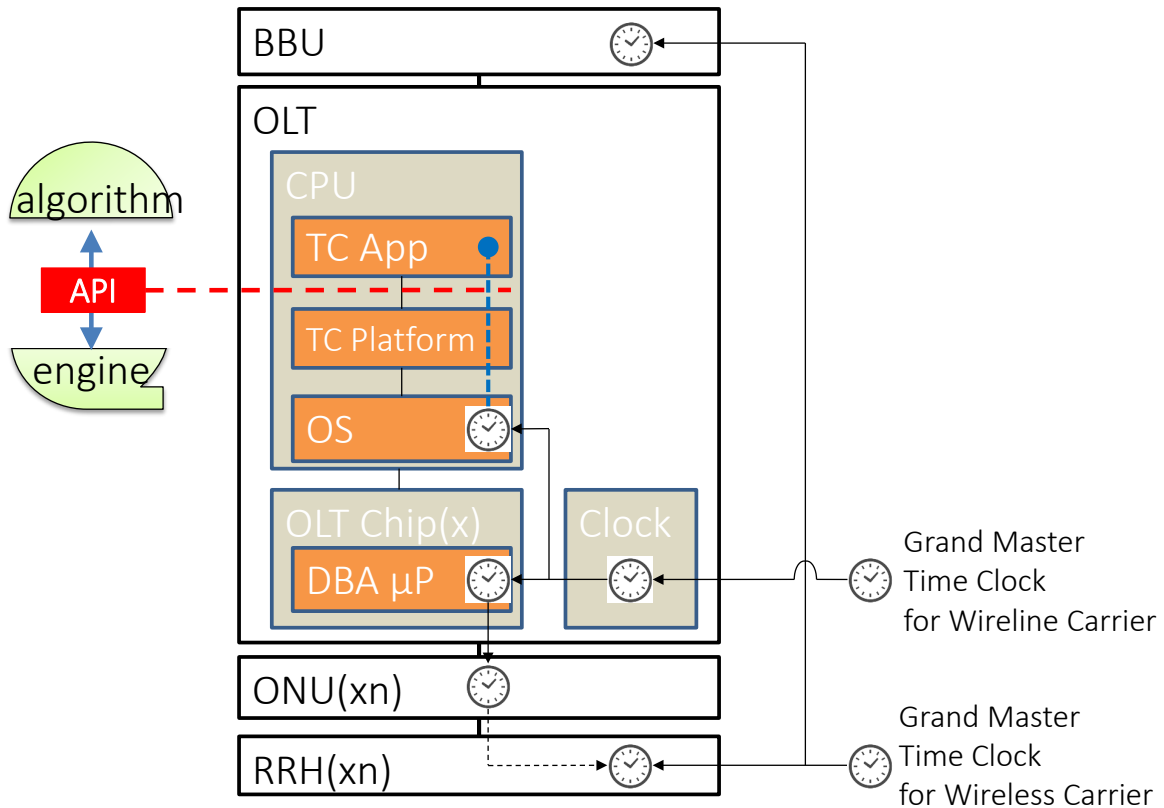


Figure 7-1 TC message handling parts

In Figure 7-1, we note that the synchronization between OLT and RRH would be described in TR-331: Architecture and Technical Requirements for PON-Based Mobile Backhaul Networks (Figure 7-2).

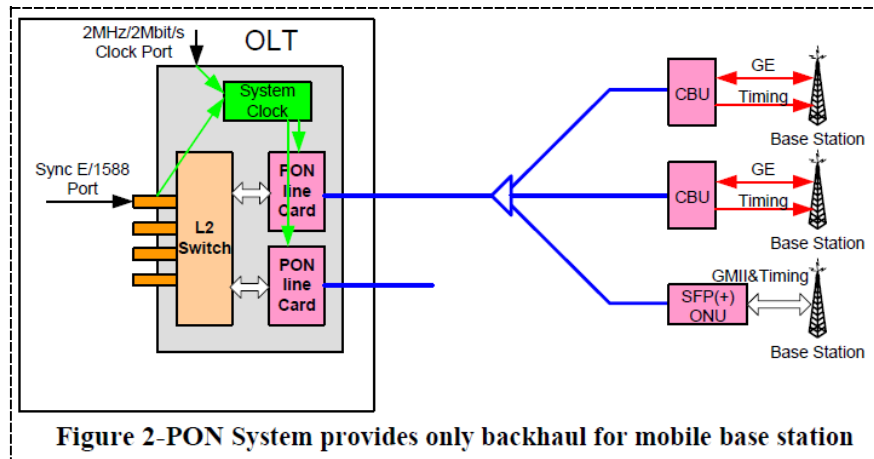


Figure 7-2 PON system provides only backhaul for mobile base station (from Fig.2 in TR-331)

In Figure 7-3, it shows some examples of TC message handling across time-related functional parts. Also, it shows that the time constraint would be based on assumption of the time synchronization between Wireline and Wireless Carriers.

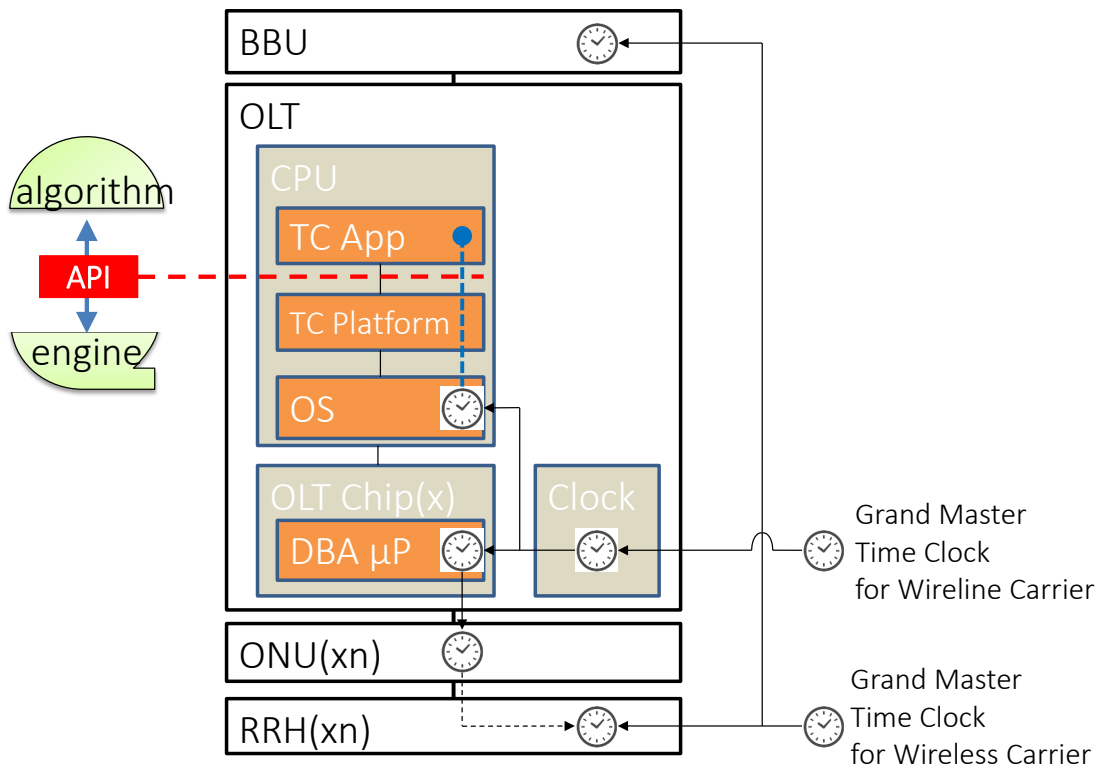


Figure 7-3 Examples of TC message handling across time-related functional parts.

8 APPENDIX B: vDBA

8.1 Virtual DBA for multi-operator/service convergence

PONs are a cost-effective solution for providing highly capillary connectivity to heterogeneous services, serving residential users, mobile cloud-RAN and next generations services. Examples are haptic feedback for medical applications, or reliable and timely exchange of control messages and camera streams in automotive applications.

Some of these new services will however require stricter QoS than simple committed rate assurance, including latency and jitter targets. From a PON perspective, this requires the development of new DBA mechanisms, which have become the focus of recent research. Virtualization of the DBA process can provide strict-QoS (i.e., capacity, latency and jitter assured services) over a multi-tenant environment.

The virtual DBA (vDBA) operates within a virtual OLT (vOLT), which is an NFV slice of a physical OLT and is associated to a VNO. The vDBA allows VNOs to control, for each T-CONT, upstream capacity, latency and jitter in a shared physical OLT, thus delivering a “True Multi-Tenant PON solution”.

8.2 Virtual DBA description

Figure 8-1 shows the comparison between today's virtualized PON and the proposed Multi-Tenant PON (MT-PON), which implements the vDBA concept. In traditional PONs, a single DBA scheme is implemented in the OLT hardware (Figure 8-1, left hand side). From hereafter, we shall refer to the DBA scheme implemented in hardware as physical DBA (PHY-DBA). In this architecture, only the infrastructure provider controls the PHY-DBA function. Consequently, in a multi-tenancy context, the VNOs are not able to directly control the DBA process for T-CONTs associated to their own customers/services, in other words VNOs don't have the ability to schedule themselves the burst allocation of their customers ONUs. Proper burst allocation by DBA is important to assure strict-QoS (in terms of jitter and latency) e.g., for low latency cloud-RAN and other 5G services. In order to assure strict-QoS services, the VNOs would then have to request and rely on SLA guarantees (bandwidth, latency, jitter) to be provided by the InP, which would manage its DBA to combine the different offered services to the different VNOs. However this would be rather static and might not be able to follow some VNOs requirements.

Alternatively, in order to enable direct control of each VNO on their own DBA process, the proposed Multi-Tenant architecture is shown in Figure 8-1 (right hand side). The description below reports the operation of three layers that are involved in the DBA process. The Physical layer takes care of framing in the data plane; the merging engine layer receives multiple virtual DBA bandwidth maps, merging them into one physical bandwidth map for the ONUs; and the virtual DBA layers, operated by the VNOs, compute a virtual bandwidth map for each slice of OLT they have access to.

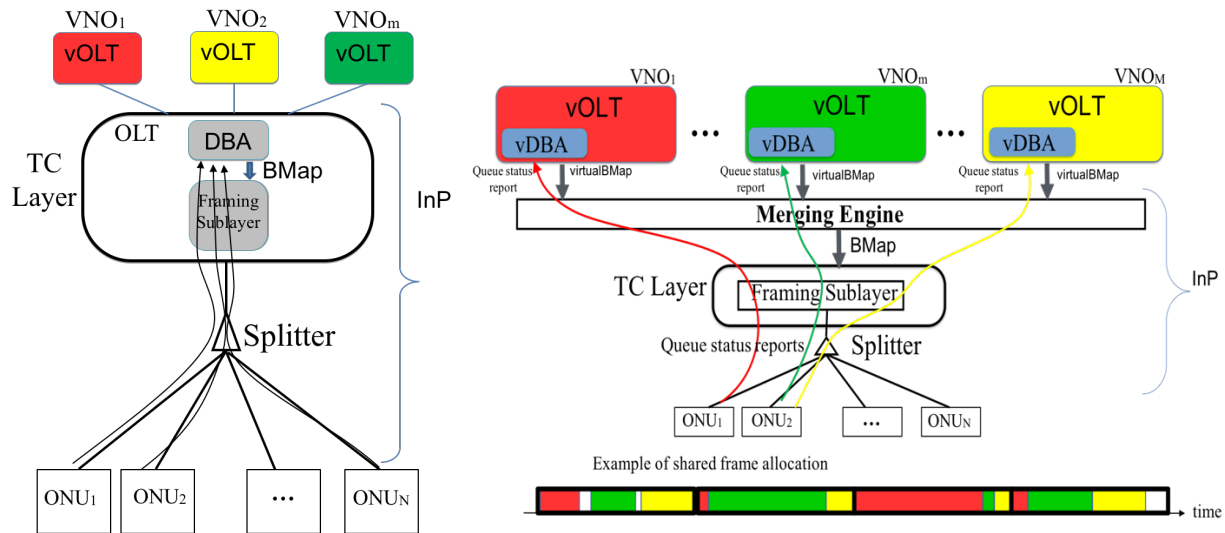


Figure 8-1 Example architecture of virtualized PON (left) vs. proposed multi-service, Multi-tenant PON architecture with DBA virtualization (right)

Transmission Convergence (TC) layer

The TC layer implements the framing and other data plane functions. The infrastructure provider is in charge of controlling this layer and will manage the different wavelength channels in a multi-wavelength PON.

Virtual OLT layer with virtual DBA (vDBA)

This is the layer controlled by the VNO, which enables full control over the choice of the most appropriate virtual DBA (vDBA) algorithm to run on the virtual PON slice. The vDBA generates the virtual bandwidth map (vBMap) for its PON slice and delivers it to the merging engine. For T-CONTs with strict latency and jitter requirements, this vBMap indicates the desired position for each slot allocation. In this way, the VNO obtains full control over the upstream capacity scheduling within each frame. The vDBA should create a vBMap based on the same frame size as the physical BMap.

Merging Engine (ME) Layer

The merging engine is the core of the MT-PON architecture. It is considered the bridge between the OLT and vOLT(s). The merging engine replaces the physical DBA layer and has two main tasks. Firstly, it relays queue status report messages (BufOcc or report frames) coming from the ONUs (from specific T-CONTs) towards the vOLT serving them.

Secondly, it analyzes the virtual bandwidth maps (vBMaps) from all vDBAs, merging them into one physical bandwidth grant (PHY-BMap) sent to all ONUs.

It should be noticed that for cloud-RAN, which has very strict latency and jitter constraints, but for which the BBU knows in advance the upstream capacity allocation, BufOcc (normally generated by the ONU), could be generated directly by the BBU, and sent to the vDBA, in order to eliminate the latency associated with the queue reporting mechanism.

The ME is controlled by the InP. The ME should send PHY-BMap to all ONU every frame (e.g., every 125 us). vDBAs however are not required to submit a vBMap every frame.

It should be noted that in order to reduce the latency between the TC layer, ME and vDBA, these might be physically co-located, for example in a system-on-chip architecture.

8.3 Quality of service classes

There should be at least three classes of service for the T-CONTs in the vDBA scheme:

- strict-QoS T-CONT, which defines latency and jitter constraints in addition to AIR/PIR. The merging engine is required to consider the specific slot allocation (i.e., start and stop position of each allocation) only for this service class.
- QoS T-CONT which only define assured rate - AIR (which is met within the few milliseconds described in existing standards)
- Non-assured T-CONT, which are allocated capacity when there is spare available.

Whenever a new service with strict latency and jitter is requested from a customer to the VNO, the VNO allocates a new dedicated strict-QoS T-CONT, where desired level of latency, jitter and availability are defined together with the capacity needed (e.g., in terms of committed rate). The vDBA sends the request to the ME, which can accept or reject it, depending on the available capacity.

Where there is overlap between vBMaps from different VNOs, the ME can move the slots allocation when generating the physical BMap with respect to their request in the vBMap, as far as the allocated slots still respect the capacity and maximum latency and jitter required by the T-CONT.

In the case where the service requiring the strict-QoS has a fixed transmission rate (or fixed within a given time length of several frames duration), there can be an additional negotiation phase during the initial allocation of the T-CONT, to mitigate the issue above. The vDBA can propose a slot allocation, which shall then remain constant across several other frames. The ME can either accept, reject, or propose modifications to the T-CONT allocation, e.g., in a way that would fit within the frame allocation (i.e., considering other similar services already allocated). The process will iterate until an agreement is reached or the service is rejected.

9 APPENDIX C: DWA use case

The DWA is a mechanism to achieve packet loss reduction during ONU wavelength mobility by taking into account buffer filling levels. This mechanism is left as further study.

End of Broadband Forum Technical Report TR-402