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Guidelines for sharing fiber/BW infrastructure for different applications and its addressing inter-operability challenges in the direction of standardizations

By Smart Cities Committee

Whitepaper

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1. Introduction

The main goal of the white paperis to provide general guidelines and issues for cooperative (infrastructure sharing) scenarioand its implications on next generation fiber-to-the-home (FTTH) networks.

To encourage the highest degree of competition, such that the freedom of choice for the end users can be maximized and monopoly can be avoided, the idea of open access is promoted. Open access supports new business models to make fiber- to- the-home (FTTH) networks an economically viable solution. FTTH networks are future-proof solutions as they support very high bandwidth but they require a high initial investment to deploy fiber in the field.So, a natural solution is sharing of the network infrastructure (fiber and equipment) among multiple network entities, which ensures that not every network entity has to make huge capital expenditures (CapEx) before being able to serve users. This reduces the barrier for network entry, encourages competition, and consequently, reduces the price of services. Open access networking can also be used to facilitate heterogeneous service provisioning (by multiple service providers) in a given network, and the important question there is how each service provider can reach to its customers in a transparent manner. In this white paper, we explore the answers to such questions.

Network provisioning can be conceptually separated into three roles, typically taken up by different entities[1], [2]:

- Physical infrastructure provider (PIP) – responsible for installation of the physical infrastructure (implying trenches, conduits, ducts, fiber, housing).
- Network provider (NP) – responsible for all active equipment between the users and the central office (CO), e.g., optical line terminals (OLTs, i.e., CO equipment) and ONUs.
- Service provider (SP) – supply of services (telephony, IPTV, broadband Internet, mobile backhauling) and installation of service specific equipment (e.g., set-top box for Digital TV).

This separation is based on the technical and economic nature of the roles. For example, providing physical infrastructure requires high CapEx, low OpEx, and low economies of scale. Network or service provisioning entails high OpEx and high economies of scale.

Open access can be offered at different layers depending on how a user selects a specific network entity, e.g., by selection of a fiber, wavelength, or a packet field (Ethernet address, VLAN tag, MPLS, IP). This classifies open access as fiber, wavelength, and bit-stream open access.

In this white paper, we discuss different flavours of open access, its control layer and general aspects.

2. Flavors of Open Access

In this section different layers are discussed on which the network infrastructure can be unbundled or opened up such that an open access infrastructure can be established. As mentioned earlier, there are three possible levels: fiber, wavelength and bit-stream.

Fiber open access

Unbundling the fiber layer means that different network sections of the access and aggregation/metro network have open access to single fibers, bundle of fibers or fiber cables. It provides a user the ability to select a network provider through a fiber. This approach allows network provider without fiber infrastructure to deploy system technology in the access and aggregation/metro network.

Fiber open access scenariouse deployed (but unused) fiberwithin a network. The feasibility of fiber open access is based upon two main criteria. Firstly, there must be a fiber-rich scenario to support open access. Secondly, there must be a physical infrastructure provider that is willing to allow access to its fiber network. If these criteria are satisfied, then fiber open access becomespossible and is the most flexible of all the available open access systems.

In fiber open access, the fiber infrastructure is only deployed by the physical infrastructure provider. In this manner network providers have the freedom to choose their technology. Also, having a discrete fiber infrastructure ensures complete isolation among all the network providers.

However, there are disadvantages like the sharing is limited to only fiber infrastructure and the migration of a user to a different network provider can be restricted as it may entail changing users' equipment to adapt to a different technology. And there is anadditional cost associated due to the need of a fiber rich deployment and associated costs due to the duplication, and perhaps multiplication, of equipment and manpower that is required.

Wavelength open access

Unbundling at the wavelength level means that every network providerhas the ability to reach customers by accessing one or more dedicated wavelengths within individual fibers. Accessing of different wavelengths by network providers is predicted naturally on the availability of Wavelength Division Multiplexing (WDM) over some (or all) network segments. In this scenario, physical infrastructure provider imposes greater restrictions on network providers than in the fiber open access system as a physical infrastructure provider coordinates the use of wavelengths by a number of network providers over an infrastructure consisting of fiber as well as WDM network devices like power splitters, arrayed waveguide grating (AWG), band splitters (BS), and wavelength selective switches (WSSs).

This flavour of open access is the most complex scheme. One of the main problem that it faces is of the coordination for accessing the wavelength. At the user end, for the reception of different services from distinct service providers, either user should have the ability of fast tuning over different wavelengths or possess multiple receivers. This requires proper coordination among different service providers. Another method to achieve this is the involvement of a neutral third party that allocates spectrum in an efficient way. Another important question associated with it is how it will be realized. For instance, in a case where physical infrastructure providerand network providers are decoupled, physical infrastructure providermay own the passive optical devices to facilitate open access. But this results in fixing that part of their network which may be unlikely. If, however, a network providerwith its own passive devices rents a fiber from the physical infrastructure provider then it may not be neutral for allowing access to other network providers. Nevertheless, wavelength open access helps in cost reduction by allowing the re-use of equipment and personnel.

Bit-stream open access

Unbundling at the bit-stream layer means there is a provisioned element on the network layer 2 (Ethernet) or layer 3 (IP). It is also known as service-level open access. Opening at network provider level instigate the competition among service providers. This also make opening less complex as competition is allowed only among service providers not network providers.

In current architectural open access solutions, the configuration of the network according to the customer choice is implemented by the network provider and the service provider then provides the service at the network provider's network edge. Service provider here has no-to-little control on the inner working of the network provider's network (also known as black box problem) and cannot troubleshoot problems end-to-end. When a customer raise any service issue,service providerand network provider lays the blame on each other resulting in the increase of cost for both service provider and network provider.

This problem can be partially resolved if network provider may share some of the network information with service providerand service provider is able to see and control some parts of the network provider's network. Another solution could be network virtualization where the network provider can separate the network into virtual slices of the network and give control of a virtual slice to a service provider.

Bit-stream open access is possible on four levels. The lowest of these (with reference to the OSI model), and specific to one architecture, is the time division multiple access medium access control layer. The next lowest is Ethernet followed by Multi-Protocol Label Switching (MPLS) in the middle, and at the top is Internet Protocol (IP).

3. Control aspects

In this section we will analyse the control aspect [3]of the open-access. This is an aspect that plays an important role when the network havepotentially several network and service providers.

Isolation

A fundamental requirement while providing open-access is a good network isolation between services and the operators in the network. The layer at which the network is unbundled decides the robustness and implementation of this isolation.

When open-access is provisioned on the fiber level, each network providercan utilise fully separated fiber strands. Hence, isolation is in built in this scenario.All this ensures that there are no interferences amongnetwork providers.

Unbundling ofthe access and aggregation network at the wavelength level offers the possibility of a high degree of isolation.This scenario also provide the feasibility of separating a batch of network providers on the basis of different wavelengths that they are using.But this is entirely dependent on the architecture that is being employed for open-access.If the architecture is utilizing optical splitters then it should be ensured that other network provider'sservices are not affected.Power splitters broadcast the optical signal and this may collide with the data of other users or network providers. To achieve a high degree of isolation, optical splitters can be replaced by wavelengthsplitting or routing devices.

Providing the open-access at bit stream level results in more significant problem as the degree of sharing in this scenario is higher i.e. in the electrical domain common forwarding resources are being used for sending data belonging to different service providers. Hierarchical quality of service is a technique that can be used to handle contention of such resources. It is implemented through the use of a hierarchical token bucket architecture. It is presently used in multi-layer Ethernet (IEEE 802.1Q) that provides different levels of quality of service.-To control the quality of servicebehaviour in the case of multiple service providers using the open access infrastructure, this scheme benefits the open access network provider to have access to the lowest level(s) of this hierarchy,while additional levels of the hierarchy can be accessed by service providerin a transparent manner. Here itcan be noticed that thequality of service and the degree of isolation is interconnectedand there is also a link with the concept of virtualization.

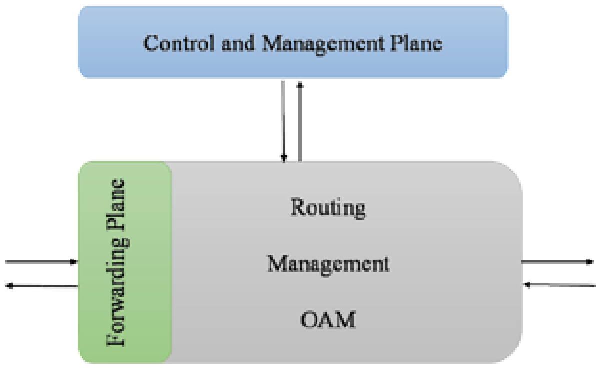
To put in a nutshell, the open access networks faces mainly the issues ofisolation and quality of service.The quality of service issue can be addressed in two ways: 1) there are issues in the architecture where the services of the users are disrupted because of a potential malicious and rogue user. Thus, proper monitoring servicesshould beprovided to first monitor any breach of safe transmissions and proper restorative mechanisms should be put in place to resume theservices of theaffected users within a reasonable time, or thedegree of isolation should be such high that this case is impossible. 2) The second problem is thefairness issues between the end users and the service providers. In open access, the problem of assuring quality of service from the perspective of the medium access control layer is a two-dimensional problem that requiresmaintaining the fairness between the users and the service providers at the same time. The complication in the bandwidth-scheduling increases when theuserswant to receive different services from different service providers.

Virtualization

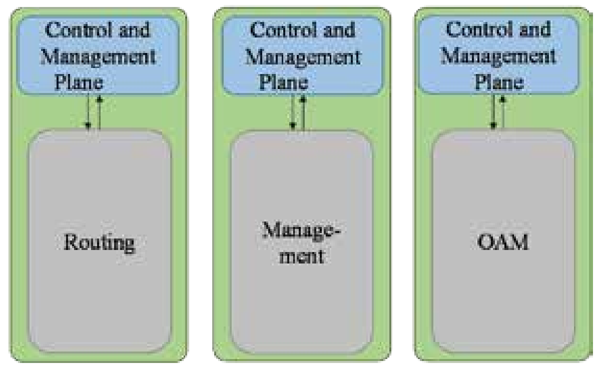
In bit stream based access the lack of integration between the service provider's network and the network operator's network causes a problem for both service providers and network operators.This problem is known as the "black box" problem discussed in section 2.

One way to resolve this black box problem is the introduction of network virtualization, where a portion of the network provider's network is given to the service providerfor management and configuration in a mannerthe service providerwishes. This implies thatthe troubleshooting process is simplified asonlyone entity can monitor and configure the whole chain of service delivery.

There are variety of ways in which network virtualization can be implemented and these ways also differ in the amount of control given to the service providers, but theneed of isolation of every network portionis its most important aspect. Inside processing of a network forwarding element is shown in Figure 1.



(a)



(b)

Figure 1: a) depicts a schematic model of a network forwarding element, and b) the segmentation of such into a number of virtual slices.

The in-built virtualization functions such as "Virtual Routing and Forwarding" (VRF) and Virtual LANs helps in implementing virtualization using currently deployed technologies.

Bootstrapping

The processes of initializing a Customer Premises Equipment (CPE) device and making it part of a network, in order to receive a set of network (e.g. Dynamic Host Configuration Protocol [DHCP]) and end-user (e.g. IPTV) services is referred to as bootstrapping.As it introduces some degree of automation to the processes of provisioning and service delivery, these processes are very important.Failure to do so leads to high Operational Expenditures (OpEx) and/or support costs. To initiate these processes first a network device (ONU) is allowedto get bit-stream access, and then theservices running on top of this bit-stream access are configured. Execution ofthese two steps depends on the technology used and type of open-access offered in the network.

The bootstrapping process can be more demandingin the open-access network than in a vertically integrated network. This is because in this process the network operator and services can be selected beforehand and the devices and the services can be preconfigured.

In a scenario with several network providers, the ONU can detect the available network providers either by using dedicated control channel or by actively probing the network for operators.

Location and identification

The main requirement of an operator is an assignment of specific postal address to an access line termination point. This assignment facilitate the execution of service features which require the postal address information, e.g.: emergency call, legal interception, fault localization mechanisms. Figure 2illustrates that by providing a dedicated fiber or wavelength connectionthe assignment of a Network Termination (NT) at the subscriber site to a specific postal address can be easily implemented. Another alternative to localize the source of data traffic received at the SCP site is to have a fixed Virtual Private Network (VPN) between NT and Service Creation Point (SCP). These mechanisms are discussed in [3].

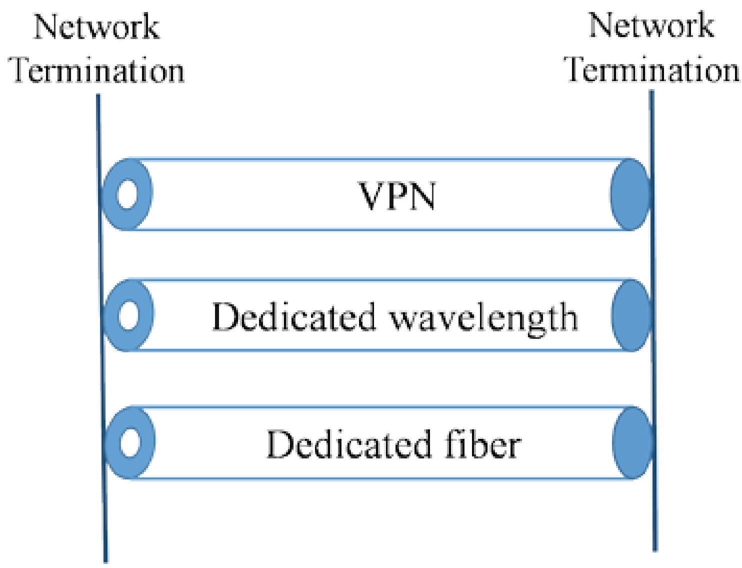


Figure 2: Examples of dedicated connections between NT and SCP

Monitoring

FTTH supports large amount of traffic from several users, for mobile backhaul systems and business accessmaking rapid troubleshooting very important. Because of remote operation monitoring is centralized and automatic. This results in operational expenditures (OpEx) savings. Ashardware and manpower costs per drop line is large so there should be no hardware upgrade(e.g. demarcation components) requirement on user side. Toincreasethe sharing factor of the investment,monitoring functionality should be shared over the complete FTTH network. Moreover, the effective fiber-fault detection and localization scheme should be sensitive to low power fluctuations and not affect data communication.

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Shared Internet Exchange

In bit-stream open-access networkswith a large degree of isolation between service providers,theremight be a problem that the traffic exchange between service providers happen at an Internet Exchange (IX) point far away from the end user. This may lead to a situation wherethetraffic between two customers (with different service providers) will be transported large distances. On the other hand, in a vertically integrated operator's network, the route of the packet could be much shorter, if the two customers are located in the "same" network.

Clearly this will lead to ahigh capacity use, longer packet delays, and overall higher costs. The solution to this problem depends upon the degree of sharing in the open access architecture. If the open access is on fiber, and wavelength layer, that will mean that there are different network providers present in a given network and the degree of sharing is low. In that case, it will make sense to have a direct tunnel between service providers(see Figure 3), using which the local traffic can be exchanged, and much like what is done in IXP. However, if the degree of sharing is high, for example, as in the case of bit stream open access, intelligent schemes could be used which filter down the local traffic within the network itself. Of course, this requires different bandwidth pipes could be established within the network itself by using techniques like virtualization or software defined networking.

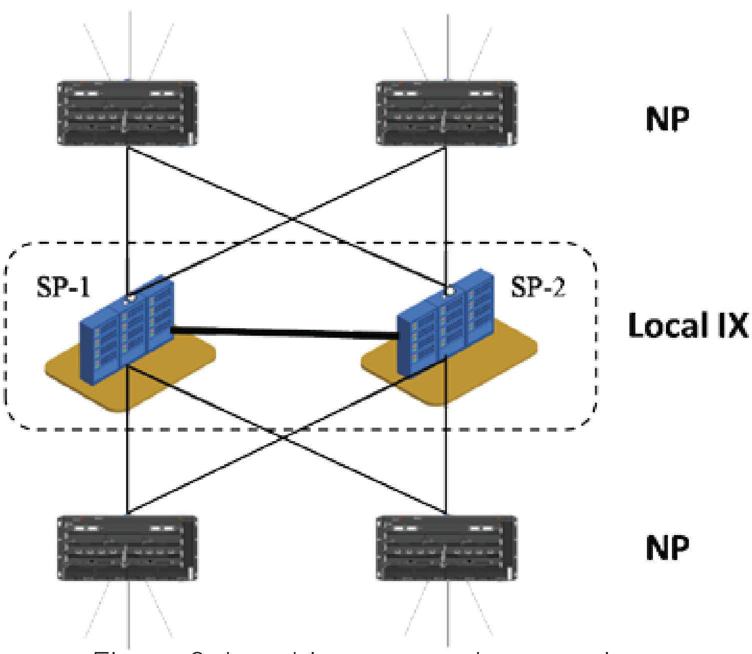

Figure 3: Local Internet exchange point

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4. General Aspects

In this section, we look into several aspects, such as data plane interfaces, control plane interfaces, physical infrastructure issues, energy efficiency concerns, effect of traffic and service level agreements on open access models.

Data plane interface

The data plane interface between the service provider and the client can be established on different layers:

a) Layer 2: Q-in Q tunnelling [4]and VLAN tagging allows service providers to create a layer 2 Ethernet connection between two customer sites. In Q-in-Q tunnelling, as a packet travels from a customer VLAN (C-VLAN) to a service provider's or data center VLAN (S-VLAN), another 802.1Q tag for the appropriate S-VLAN is added before the C-VLAN tag. The C-VLAN tag remains and is transmitted through the network. As the packet leaves the S-VLAN in the downstream direction, the S-VLAN 802.1Q tag is removed.Althoughthe routing and separation issues are solved, this method does not allowservice provider to map an IP address to a customer. This issue could be solved by enabling DHCP option 82 extension on the access switches at the network provider.The network provider can provide information about which customer is connected to which switch port. In this way,aservice providercan learnfrom which customer a DHCP request came from, and therefore also know theIP address of a customer. Service providers and the network providerneed to maintain only limited amount of cooperation to agree upon the mapping of service with the VLAN ID.

b) Layer 2.5:MPLS labels per customer and service could also be used instead of VLAN tags. As the MPLS allows for a large label space, this could be easilyimplemented. Moreover, theMPLS OAM functions, such asMPLS Transport Profile (MPLS-TP) Operation and Management (OAM) functions could be enabled for the service provider. This will make the fault detection and monitoring easy.

c) Layer 3:Layer 3 could also be used for bit stream open access. Network providers can manage the assignment of IPv4 addresses and can use the routing protocols like open shortest path first (OFSP) for routing the traffic. The service providercan detect the type of service based on the destination address or other properties of the packet. However, there are many vital questions that needs to be answered? For example, does anetwork provider control the entire address space or the service providers are allowed to use their private address space.

Control plane interface

In control plane topological aspects could be shared partially thatcould be used at the two ends for error identification. This is similar to the conventional case, where the control plane is completely accessible to the service provider. Some of the mentioned problems can be tackled by this function. For example, anetwork providercan provide selected SNMP information to the service provider, usingwhich the service providers can verify that the network provider's network is working normally.

This will help in providing the support by simplifying the interaction and reducing the amount of troubleshooting between the two.

In accordance of the type of data plane, the interface should handle the transfer of routing information, for example via Border Gateway Protocol (BGP) or OSPF. If virtualization option is also offered by data plane to theservice provider then this interface should provide a secured communication link between the two networks.

Energy efficiency

As an openaccess network entails sharing of the network infrastructure it brings definite dividends in terms of energy efficiency. It is also evident that the bitstream open access shares the network infrastructure end to end and thus it maximizes the sharing. Let us take an example where the same set of users are served by bit stream architecture and by an architecture that is open only on fiber layer. In the latter case, the different network providers have to duplicate both the passive and active equipment and thus both the carbon footprint and the operational expenditure of the network open on fiber layer will be higher.

The result of this sharing is that the overall energy use is lower compared to several vertically integrated operators. Thisenergy saving leads to overall reduction in OpEx, besides the reduction in CapEx.

Service-level agreements

Conventional SLA schemes focus on one-dimensional SLA mechanisms where the bandwidth distribution among different users are looked into. In open access architectures, the bandwidth is shared between different service providers and different users. This will make the SLA provisioning a two-dimensional problem. Thus, newer medium access control protocols will also be required which guarantees the SLA to both service providers and the users.

Physical infrastructure aspects

As we go higher up in the layers to provide open access, the flexibility of the network architectures increases, however the sharing becomes limited.

Fiber open access provides complete flexibility to the network providers to choose and design their own network architecture, however the customer migration may become problematic.If traffic is handed off at layer 1, the network provider would have a monopoly on all premises connected on that network. This severely restricts the customer migration and thus preventing competition. The network providers may adopt different heterogeneous technologies, and this will further prevent anycustomer churn. Fiber open access is possible in a fiber rich scenario, where the physical infrastructure providerdeploys extra unused fiber within the network.

Open access at the WDM layer is difficult. New components will be required in the network design which can distribute wavelengths among different network providers efficiently and fairly. These new components may further entail changes in the power budget of the network and thus the network may have to be re-dimensioned. A separate entity may be required for book keeping of the spectrum distribution and spectrum use. The spectrum allocation must further be done in a dynamic way so that different network providers with different customer base can be dealt with fairly. Further, the open access architectures should support customer churn, that is, the migration of customer form one network provider to another network provider. This will further necessitate that the provisioning of spectrum allocation must be done in a dynamic way. Another issue which will pop up in the open access at the WDM layer is of network isolation. Network isolation requires that no network provider should adversely influence the services of another network provider, and this will require network monitoring, where there is a proper regulation of who transmits what. If network isolation is not guaranteed per se, network providers will not be willing to participate in the open access network.-Furthermore, for wavelength open access, in order to provide access to every network provider the physical infrastructure provider may need to own the unbundling element. Being the owner of the network element, the physical infrastructure provider ceases to be technology agnostic. One of the network provider can also be the owner of the point of unbundling. This scenario is the most likely onein case of unbundling and the network providerin this case is known as the master network provider. But this scenario of master network provider should avoided to ensure neutrality for pure open access. This will also necessitate that there should be a same technology used by allnetwork providers. However, such scenarios are very complex and may not be cost effective.

Bit-stream open access is simplest to implement as the service providers get a pie of the network resources on the electrical level. In some sense, this is quite similar to unbundling in the copper world, and thus methods to implement bit-stream are fairly known and less challenging. The only major concern of service providers in the bit stream open access is the black-box problem which we have already detailed before.Other challenges include address assignment, implementing routing protocols, managing peering with network provider/service providers, migration to IPv6, and implementing IP multicast protocols.

Traffic and its influence on open access architecture

The largest source of traffic in FTTH networks is streaming video services.Even though the on-demand services are increasing, but broadcasted TV data will continue to remain predictable. The time of soap operas, important football or cricket matches, and the time popular movies are broadcasted still remain predictable.This shows the importance that caching techniques can play in the context of both making networks energy efficient and reducing the load in the backbone network. In the open access architectures where different service provider participate to deliver the same content to different users, new caching techniques should be used where the different service providers are sharing the same cache server.

References

[1] A. Dixit, M. Van der Wee, B. Lannoo, D. Colle, S. Verbrugge, M. Pickavet, and P. Demeester, "Fiber and Wavelength Open Access in WDM and TWDM Passive Optical Network," IEEE Network (2014), pp. 74-82.

[2] M. Der Wee Van, K. Casier, A. Dixit, B. Lannoo, S. Verbrugge, D. Colle, and M. Pickavet, "Techno-economic evaluation of open access on FTTH networks," IEEE/OSA Journal of Optical Communications and Networking (2015), 7(5), pp. 433-44.

[3] OASE WP4, D3.3, Cooperation Models.

[4] IEEE Interworking Task Group of IEEE 802.1Q, "Local and metropolitan area networks Virtual Bridged Local Area Networks", standard 802.1Q-2005, 2005.

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