Provision of Metro Ethernet services using a reconfigurable photonic access network

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The paper proposes a design for traffic engineering to provide Ethernet services using an extended access network. Ethernet has remained the dominant technology for Local Area and Enterprise Networks, the use of Ethernet in metro networks has seen significant interest of late to provide for end to end Ethernet services to the user. The Broadband Photonic (BBP) access network is viewed as a quasi independent stack of EPONs in which geographically spread customer-VLANs (C-VLANs) can be implemented. The use of such a network for providing metro Ethernet like services in addition to traditional access services is presented.

Introduction

The BBPhotonics (BBP) project under the Freeband consortium looks into the design of a flexible and re-configurable extended access network. Fiber to the Home/Curb/Business (FTTx) is seen as a promising means to deliver the benefits of fiber in access networks and Passive Optical Networks (PONs) is a technologically popular and feasible means to implement FTTx. Legacy PONs use a downstream broadcast from the Head End (HE) to the end user and a Time Division Multiplex (TDM) arbitrated upstream transmission from the end user to the HE. The BBP network is viewed as an upgrade mechanism for such PONs with a Dense Wavelength Division Multiplex (DWDM) overlay where several quasi independent TDM based PONs operate on independent wavelength pairs. The aggregate bandwidth supported by such a network is increased because multiple logical PONs are supported. There is an element of switching introduced between the logical PONs which allows for inter-PON bandwidth distribution. The network can be used to provide for metro Ethernet like services by using individual logical PONs to implement Customer V-LANs (C-VLANs) in addition to traditional services offered by access networks.

Network Design

The Head End (HE) will house multiple Optical Line Termination Units (OLTs) each operating on a unique wavelength pair. The HE is connected to multiple Remote Nodes (RNs) in a ring configuration. The RNs incorporate a micro ring resonator based Reconfigurable Add/Drop Multiplexer (ROADM). It is possible to add/drop any wavelength pair towards the Customer Premises Equipments (CPEs) The CPEs house the Optical Network Units (ONUs). The ONUs are wavelength agnostic and can be uniquely associated with a single OLT depending on the wavelength pair add/drop towards it. Each OLT and the associated ONUs form a logical Passive Optical Network (PON). There are several such logical PONs depending on the number of wavelength pairs used in the network. The nominal bandwidth available to each ONU will depend on the number of ONUs supported by the individual logical PON. Any ONU can be reassociated with a different PON by changing the add/drop wavelength towards it. This will allow for a capability to dynamically re-allocate the increased aggregate bandwidth supported by the network. Fig 1. illustrates the schematic of the network as a two stage switch with only two OLTs and five ONUs for clarity. The first stage switch can be implemented by a Gigabit Ethernet Switch (GbE) at the Head End (HE) and the second stage switch will be the access network itself which can dynamically associate distinct set of ONUs in the CPEs with any one OLT at the HE.

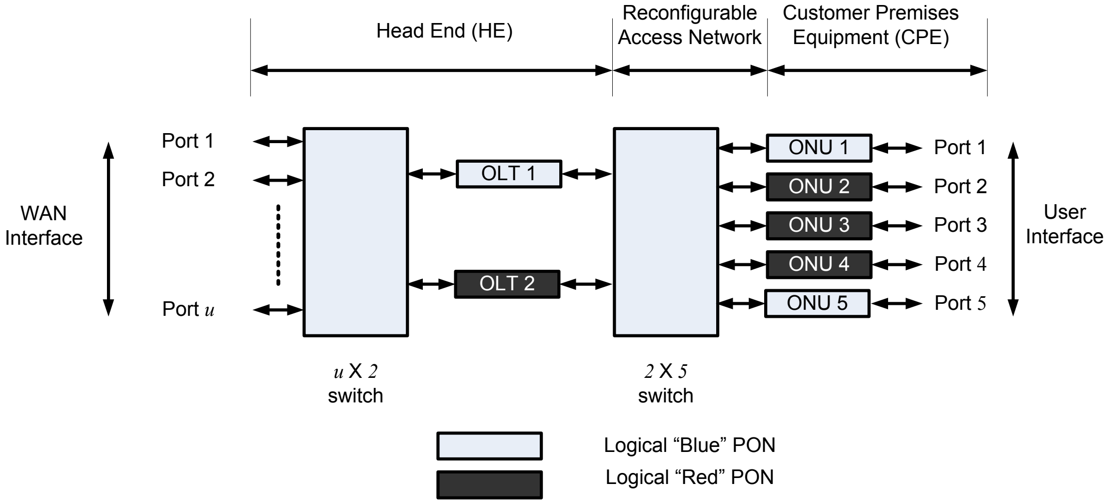

Figure 1: Network view as a two stage switch

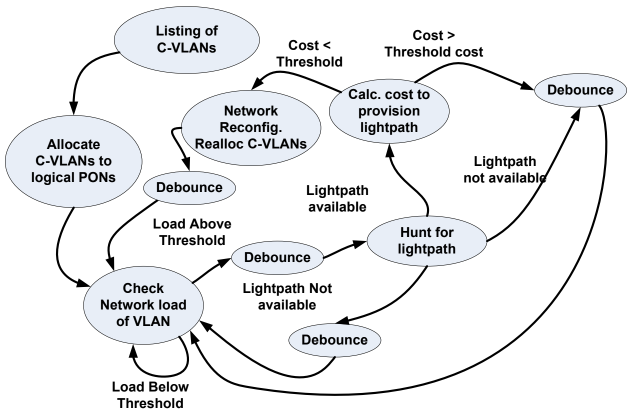

Figure 2: State diagram for C-VLAN allocation

Implementation of customer VLANs

Geographically distant Local Area Networks (LANs) can be configured to operate as a single customer Virtual LAN (C-VLAN). The IEEE 802.1Q VLAN tagging techniques are used in the Metro network domain to extend Ethernet networks. The unique network architecture of the BBPhotonics network gives an option to do the same with an extended access network. The ONUs here act as the Provider Access Points (PAPs) where the C-VLANs connect. The proposal is to use a port based identification to group customer VLANs. Hence each PAP can support multiple VLANs but with the restriction of belonging to a single C-VLAN.

A heuristic algorithm for C-VLAN grouping in the network is illustrated in Fig. 2. The network will designate certain ONUs as PAPs. The number of PAPs supported depends on the network operator. The fitting algorithm tries to have all the ONUs which form a part of a single C-VLAN on a single logical PON. This is subject to the constraint of being able to provide a lightpath to all such ONUs on a single logical PON. The grouping of one C-VLAN on a single logical PON will reduce network leakage and in addition limits the intra C-VLAN communication to a single logical PON. The network also seeks to always maximise the available bandwidth to the user and it is possible that the bandwidth requirements are not met with all C-VLANs being supported by a single PON. This will trigger a reconfiguration of the network to support the C-VLAN across multiple logical PONs subject to the constraint of a lightpath being available. Fig. 3 illustrates the case with C-VLAN support in a single and in multiple logical PONs.

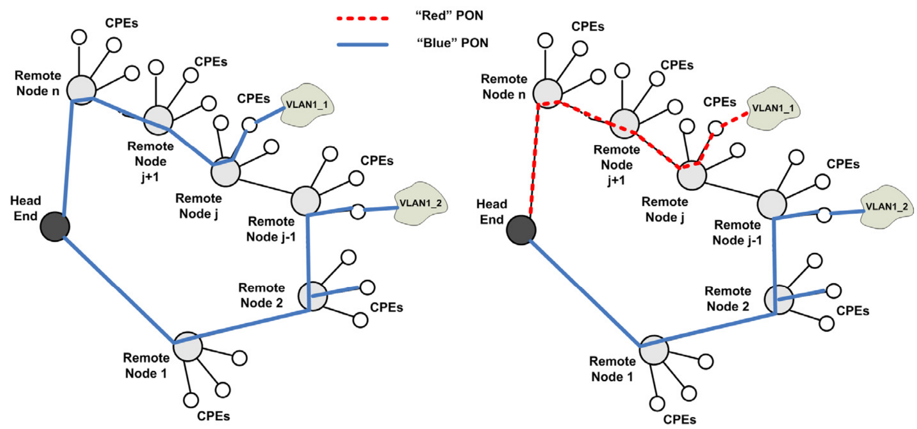

Figure 3: C-VLAN support in a single and multiple logical PONs

Performance Characterization

Simulations are performed with OPNET Modeller to illustrate the performance of a C-VLAN with VLAN1_2 hosting a server farm and the VLAN1_1 hosting a 50 user LAN segment doing FTP downloads. The bandwidth demands for VLAN1_1 are asymmetric with more demands in the downstream direction. For VLAN1_2 the requirements are the opposite. In profile 1 the switching is initiated at 500 s while in profile 2 this is done at 100 s. The maximum available bandwidth to the user for FTP downloads increases from 100 Mb/s to 800 Mb/s. The switching time is nominally taken as 200 ms. The intra PON bandwidth distribution scheme is presumed to be a simple fair sharing scheme. The dynamic switching ability allows for optimization in bandwidth availability to the user.

Conclusions

A traffic engineering concept for a re-configurable multi-wavelength EPON based access network is proposed. The design suggests using of an extended access network infrastructure to provide metro Ethernet like services in addition to providing traditional services of an access network. A heuristic algorithm is presented and a user case is studied by means of characterizing the FTP response of a user LAN connected to a geographically distant server farm location.

References

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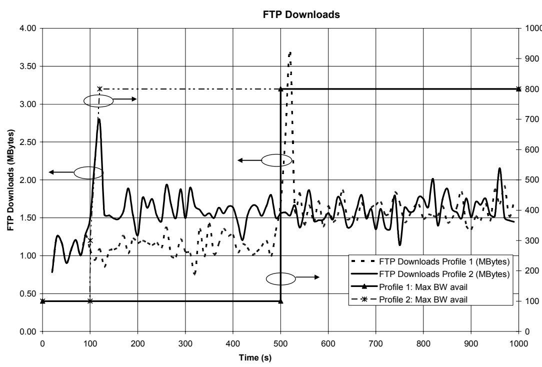

Figure 4: FTP Downloads in VLAN1_1

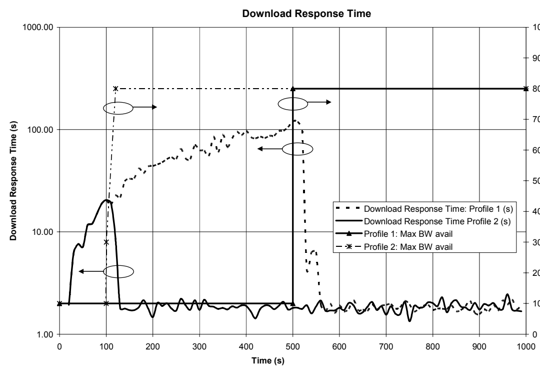

Figure 5: Download response time in VLAN1_1

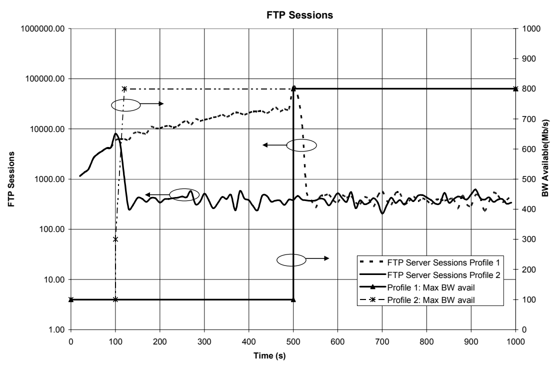

Figure 6: FTP sessions hosted in VLAN1_2