International Journal of Computer (IJC)
ISSN 2307-4523 (Print & Online)

http://ijcjournal.org/

Supporting Service Differentiation in Multi-domain Multilayer Optical Networks

Wajdi Halabi*

University College of Science and Technology (UCST), IT and CS Department, Khanyounes, Gaza strip, Palestine

Email: w.halabi@cst.ps; wajdi.alhalabi@gmail.com

Abstract

Providing differentiated quality of service became more and more important. This is not only because some service requests a high quality and real time transportation, but also because other services such as the capacity greedy applications request a higher bandwidth. In the meantime, has been the hybrid architecture consists of IP/MPLS domain and ASON/GMPLS optical domain projected as the infrastructure of the future internet. This architecture supports the transportation of the in near future expected data traffic on the ASON/GMPLS over DWDM optical domain, whereas it supports all the IP based service applications using the IP/MPLS domain. However, supporting service differentiation in multi-domain multilayer optical networks require the invention on routing scheme that supports both routing policies, the Physical Topology First (PTF) and Virtual Topology First (VTP), which are used to accommodate traffic in multilayer networks. In this work we use a hierarchical routing algorithm to evaluate the service differentiation schemes that are known in the literature in an IP/MPLS over ASON/GMPLS multi-domain network scenario, these service differentiation schemes are the Routing Policy Differentiation (RPD), Virtual Topology Differentiation (VTD) and Virtual Topology Sharing (VTS).

Keywords: DiffServ; Service differentiation; QoS; DWDM; IP/MPLS; optical networks, multi-domain multilayer; ASON/GMPLS; topology abstraction; IP/WDM.

1. Introduction

The incessantly growth of bandwidth capacity request because of predicted data traffic in the anticipated contemporary telecommunication networks has proposed the challenge to the future Internet network; consequently, was the demand expected for a novel Internet network infrastructure, which is able to serve the predicted vast demand for data traffic.

----

* Corresponding author.

Dense Wavelength Division Multiplexing (DWDM) can provide networks support all-optical high-speed channels up to 10, 40 and 100Gbps [1]. Therefore, DWDM has seemed to be the ideal transport technology and got much attention in long-haul and metro/regional networks [2]. This has driven the production of circuit-switching capable devices like optical cross-connect (OXC) and optical add-drop multiplexer (OADM) devices. moreover, there has been advancement within the design for optical networks. IETF generalized multi-protocol label change (GMPLS) framework [2] has tailored packet-based multi-protocol label change (MPLS) for provisioning ''non-packet'' circuit-switched connections, i.e., through label abstractions for wavelengths, timeslots, etc. GMPLS contains key add-ons for routing, signaling, and link discovery [3], GMPLS integrated infrastructure brings each technologies along ''non-packet'' circuit-switched connections [4, 5]. MPLS have been altered to suite with routing constrains in optical networks; hence MPLS allow optical devices like Optical Cross connect (OXC) to establish automatically Optical Label Switched Paths (OLSP). OLSP are MPLS optical connections, whereas the wavelength represents the labels [4,5,6], It has been determined that the GMPLS control plane decreases OPerational EXpenditure (OPEX) [7]. Meanwhile the Automatically Switched Transport Network (ASTN), known as ASON (G8080), has been proposed by the International Telecommunication Union — Telecommunication Standardization Sector (ITU-T). This was triggered by the motivation to establish an automated optical connection establishment via the management of the signaling and routing in a network, which can replace the slow and error liable manual intervention. The drawback of ASON that it is not proposing a protocol but only describing architecture defines a control plane the components and the interaction between these components. This reality makes the ASON/GMPLS association worthy. Meanwhile the IP/MPLS became successful the routing protocol that can avoid the drawbacks inherited in the IP packet switching, such as the concerns about the speed and scalability, the out of order arrival and the quality of the transition as there is no pre-negotiation between sender and receiver to determine the bandwidth needed for the connection. These facts have made the association IP/MPLS based ASON/GMPLS to be predicted as the preferred infrastructure in the future Internet. In IP/MPLS over ASON/GMPLS network architecture is able to setup optical link in combination with the Traffic Engineering (TE) features which are supported traditionally by MPLS protocols. This has evolved the known Multilayer TE (MTE) paradigm in an integrated routing manner [8, 9,10,11], which gives the capability to establish links on the IP/MPLS domain, by aggregating traffic on the residual bandwidth available in the optical lightpathes, which is known as grooming technique. The other opportunity is to accommodate traffic links on a new optical connection in the optical layer. The incorporation of both techniques has assured that the cross-layer collaboration can enhance the resource utilization and so rises Return on Investment (ROI). Hence IP/MPLS over ASON/GMPLS networks has been projected to be the favored architecture for the upcoming Internet network [10]. Most of services are tending to use the Internet Protocol (IP) layer to transmit the traffic, while these services are varying from real time application like VOIP, telemedicine..etc to bandwidth and packet lost sensitive applications like banking sector. This traffic variety over IP has revealed the necessity for improving the classical Quality of Service (QoS) towards a Differentiated Service (DiffServ). Accordingly, network operators have been obligated to move towards (DiffServ) approach trying to higher the ROI [12]. DiffServ is known as a scalable technology, which provides the QoS level based on an arrangement, which states the operator's obligations in terms of constraints such as availability, delay, jitter and packet loss. DiffServ has also been incorporated with the MPLS protocol [13]. As MPLS protocol establishes connection oriented Label Switching Paths (LSPs) and hence it decouples routing from traffic forwarding, which improves the TE in the IP layer [14, 15]. In all-optical channels (lightpath) can be established in DWDM the Lightpaths bypass electronic packet switching at transitional nodes and improve communication quality in terms of end-to-end delay, jitter and packet loss. The IP/MPLS based ASON/GMPLS networks need to offer transport for a diversity of applications, which having diverse Quality of Service (QoS) needs. This entails that the Differentiated Service paradigm, which advances the QoS in pure IP networks, must be extended to the new underlying infrastructure. However, introducing DiffServ is optical multi-domain networks poses additional challenge, as the restrictions routing in multi-domain must be taken into account. Currently there are more than 29.000 interconnected decentralized networks combining together the Internet network. These decentralized networks are known as domains or Autonomous Systems (AS) structured on a well-known network hierarchy. In this structure picking a route to convey traffic for an end to end connection is identified as multi-domain or inter-domain routing. Multi-domain routing has been well studied and well analyzed in pure IP (packet) switched networks. This is not the situation in circuit switched networks, as the security and scalability propose especially in optical circuit switched networks a number of routing challenges. For security and scalability reasons, network operators would not sustain the full state information of their network across the Internet network, accordingly it is understandable that some kind of information aggregation and distribution is essential in multi-domain scenario to keep the domain internals hidden from other domain operators, and to avoid heavy traffic load produced by the huge amount of data carrying routing information. The techniques of topology abstraction and hierarchical routing have been developed to tackle these problems. These techniques have been widely studied for packet-switching IP and/or cell-switching asynchronous transfer mode (ATM) networks [16, 17]. Some studies have proposed the application of topology abstraction and hierarchical routing within the environment of optical multi-domain networks [18, 19, 20]. Providing conveyance for a diversity of applications, which have different QoS requirements within optical multi-domain networks requires the extension of DiffServ technique to make MTE more efficient. Whereas the routing restriction in multi-domain networks must be considered, as only abstracted form of routing information of one domain is available for other domains. In this study we will investigate the possibility to improve the advertisement of service differentiation in optical IP/MPLS over ASON/GMPLS multi-domain networks. This requires the proposing of a novel inter-domain routing scheme, which provides an elaboration to the Traditional MTE introduced in IP/MPLS over ASON/GMPLS networks and do not violate the restrictions of scalability and security. In this study we propose the introduction of DiffServ in IP/MPLS based ASON/GMPLS multi-domain, so we first and introduce three service differentiation techniques:

1. Routing Policy Differentiation (RPD). In the multilayer routing scenario, RPD algorithm decides based on the Class of service (CoS) the request for connection belongs to.
2. Virtual Topology Differentiation (VTD). This scheme creates multiple virtual topologies, whereas each one is used to settle the traffic belonging to certain CoS.
3. Virtual Topology Sharing (VTS). This scheme allows limited resources sharing amongst diverse virtual topologies.

In this research study these techniques are adopted and their impact on the service differentiation in IP/MPLS over ASON/GMPLS multi-domain networks has been evaluated. To do that, we will examine the three DiffServ schemes proposed in a related work studies have been proposed for single domain networks [21]:

1. RPD Service (RP-Diff). This scheme is simply based on the RPD algorithm.
2. Virtual Topology Hard Differentiation Service (VT-Hard-Diff). This technique applies the RPD algorithm jointly with the VTD scheme.
3. Virtual Topology Soft Differentiation Service (VT-Soft- Diff). This approach combines all of the three schemes (RPD, VTD and VTS).

2. Related work and contribution

Several studies have addressed application of Service differentiation in IP/MPLS over optical networks, which indicates its importance.The study in [23] has investigated the Grad of Service (GoS), which has been determined as the quality provided, which has been evaluated based on link set up time and blocking ratio. GOS stays in contrary to QoS, as QoS is defined as the quality provided after the link creation. In this study three mechanisms for GoS differentiation in a DWDM network are proposed. The first strategy suggests the resource reservation for high-priority (HP) requests. The authors set a limit to define the quantity of resources that should stay obtainable for HP demands at the costs of low priority. The second scheme is using an algorithm which assigns a larger amount of routes to HP traffic. This scheme produces a smaller blocking ratio for HP connections but the setup time can be higher because of the higher number of tries the systems performs amongst the available paths. The last proposed GoS scheme is based on the pre-emption of low-priority (LP) requests if the system does not find adequate resources for HP traffic. In [14] the authors propose a multilayer mixture on-line/offline routing algorithm. Where the HP traffic is established via an off-line system, which finds the optimal route based on a foreknown traffic matrix. HP traffic is directed in a real-time mode applying an on request route calculation based on the state of network. To assurance a lower blocking ratio to gold requests, the system must be equipped with a preemption module, which is happening at the cost of the LP traffic. A differentiated optical service model has been proposed in [24]. The model uses optical factors to categorize the lightpaths. These factors such as the wavelength’s quality and reliability and they are also defined in quantitative terms (delay, normal piece mistake rate (BER), jitter and data transfer capacity) or dependent on utilitarian competences (monitoring, protection and security). Diverse CoSs are established onto diverse lightpaths based on the demanded service quality. Wei and his colleagues [25] recommend a cross and incorporated QoS control calculation for IP over optical systems, which joins an affirmation control calculation at the IP layer with a lightpath separation in the optical domain. IP traffic having a place with various CoS is built up onto high quality and low quality lightpaths. The lightpaths are arranged dependent on the estimation of the BER and on some subjective parameters, for example, survivable, secure, pre-emptible. Puype and his colleagues [26] gift a preemptive MTE technique and assess its appropriateness to a multiservice setting. The MTE formula created from multiple cross-layer TE procedures. the primary procedure consists of (re)routing IP/MPLS traffic through a shortest path formula. The formula relies on a value perform that will increase the IP/MPLS link usage whereas avoiding congestions. The second procedure relies on the IP/MPLS logical created topology, that integrates the antecedently mentioned load-based price perform with an increasing optical metric [27]. The third procedure relies on IP/MPLS connection capability up/downgrade that changes the quantity of accessible capability regardless the topology property. parenthetically the appropriateness of the instructed MTE strategy, the authors demonstrates however dissimilar optical price metric and various provisioning modes influence the QoS parameters. this suggests that during a multi-service setting the optical price metrics and therefore the provisioning manners should be chosen permitting to the CoS. Motivated by the fact that the selection of the MTE routing scheme influences the accessible QoS as moreover because the resource usage the authors of [21] propose and describe three DiffServ techniques. the primary technique is named RP-Diff, that relies on the RPD technique is choosing the routing policy in a very multiservice infrastructure with relevance the traffic needs. However, the authors reveal that the RPD has no influence on the QoS differentiation since dissimilar services are aggregated on the same OLSPs. to boost the RPD efficiently, the authors propose another plan called VT-HardDiff, made dependent on the VTD method. This method is utilized to move assorted CoS over diverse virtual topologies. This procedure is employed to transfer numerous CoS over numerous virtual topologies. The resource virtualization in IP/MPLS over ASON/GMPLS networks, provides the chance to take numerous virtual topologies freelance from one another. This procedure provides differentiated QoS levels, however the results shows that the VT-Harddiff worsens the performance compared to RP-Diff technique. to induce over this drawback, supported the VTS technique, the authors planned a heuristic known as VT-SoftDiff. This approach may be a variation of the VT-HardDiff technique. The ends up in [21] prove that a mixture of RPD, VTD and VTS should be taken into thought whereas coming up with a DiffServ theme for increased IP/MPLS over ASON/GMPLS networks. Related work clarifies that service differentiation in IP/MPLS over optical networks has attracted recently major awareness in the research community. Even though our analysis shows also that all of the studies in related work have investigated DiffServ in IP/MPLS over optical networks only in single domain network scenario. This study investigates the service differentiation issue in IP/MPLS over optical multilayer multi-domain network. It tests and evaluates the DiffServ effectiveness of the three schemes (RP-Diff, VT-HardDiff and VT-SofftDiff), which have been proposed based on the routing schemes (RPD, VTD and VTS) in [21].

3. System architecture

3.1. Node architecture

The projection of IP/MPLS over ASON/GMPLS to be the popular design for the future internet network infrastructure [5] has moved internet Service providers (ISP) to prefer one network infrastructure with each styles of conveyance, that consists of a hybrid multi-granularity design as well as associate degree IP/MPLS packet shift fabric alongside a fiber/wavelength shift fabric (e.g. ASON/GMPLS) that gives encapsulation and versatile manageableness for larger high-bandwidth circuit/tunnels.

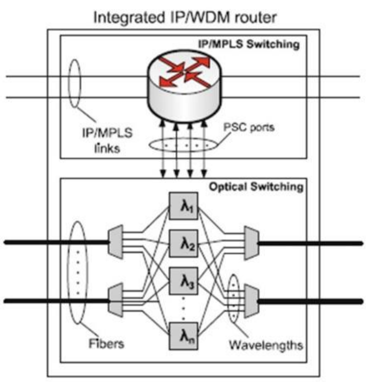

Figure 1: Integrated IP/WDM node model [6]

This architecture permits cross-layer styles that enhance the resource utilization and decline the OPEX/CAPEX [8]. within the simulations for this study, we tend to think about a simplified design of combined IP/MPLS over optical networks whereas each node has the design given in [10] (Figure 1). This node design permits an operator to manage the packet and optical domains as if they were one domain.

3.2. Network model

The simulations are going to be accomplished on an IP/MPLS-based ASON/GMPLS investigation framework, that is generated using the network simulation tool OMNET++ [28]. This test framework encompasses seven domains, which are connected via eleven unidirectional inter-domain links (Figure 2); for correct inter-domain performance and inter-domain connectivity, the common inter-domain links per domain is 3.14. The nodes are prepared with sixty-four ports, whereas every fiber has thirty-two wavelengths every having the ability to set up 10Gbps OLSPs.

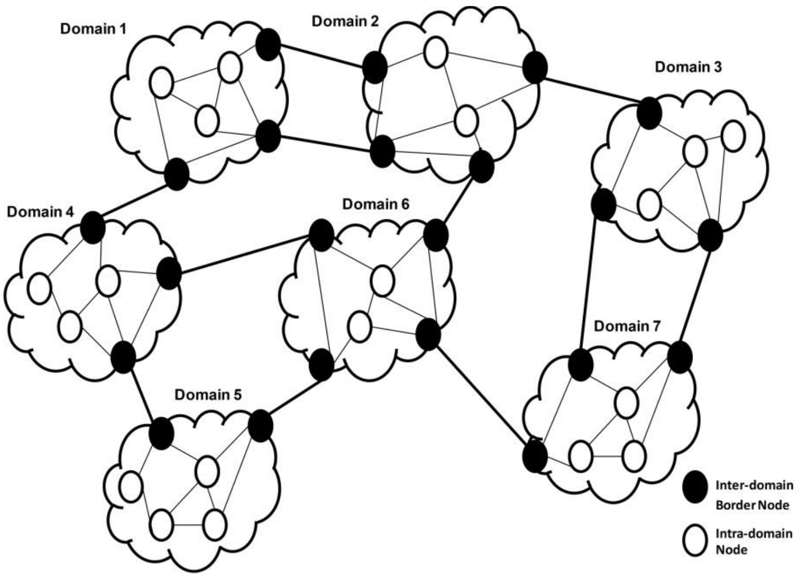

Figure 2: Test network topology

3.3. Traffic model

In our simulations we monitor the traffic requested in the network, which is the services sold by SP as a set of demanded connections. Each service request will be modeled with a LSP request belonging to certain CoS. In this research work we will investigate two CoS levels: the HP and LP, the previous are going to be appointed to traffic conveying services with high QoS necessities, like real-time applications having strict service availableness and end-to-end delay necessities. The simulations are carried out in multi-domain network framework. The LSP request are generated in line with a Poisson process with average rate $\lambda=1/Tia$, where Tia is the connection inter arrival time. and connection holding time Tht exponentially distributed with mean $1/\mu$, the traffic load L is calculated according to the following formula:

$$L = \frac{\lambda}{\mu} \cdot \frac{\text{Cav}}{\text{COLSP}} = \frac{\text{Tht}}{\text{Tia}} \cdot \frac{\text{Cav}}{\text{COLSP}}$$

COLSP is the OLSP capacity and Cav is the average capacity of all the accommodated LSP requests. whereas the connections are generated by a connection generator amongst arbitrarily designated nodes and domains employing a 70/30 intra/inter-domain quantitative relation. this can be chosen to replicate real networks which can probable field more intra-domain requests. source and destination of a connection request are chosen arbitrarily using a uniform distribution. The produced requests for connection are characterized by the quadruple {s, d, Creq, c}, wherever "s" and "d" are the service request's source and destination IP/MPLS routers, which are randomly elected amongst all the network nodes; Creq is the capacity demanded by the connection request and it's arbitrarily selected in line with a uniform distribution between 100% and 30% of the OLSP path bandwidth; c is the CoS, which is set in order that the 30% of the made LSP demands belongs to the HP CoS, while the 70% are of the LP CoS. To test the system under various load circumstances, the traffic load is enlarged little by little at constant intervals throughout the complete period of the simulation. To enlarge the traffic load, the connection request inter arrival time T_{ia} is about to 0.067 s, however the connection holding time T_{ht} is enlarged from a minimum of 100 s to a most of 300 s. To determine the connection blocking ratio, the simulations have been carried out with 10^6 requests for connection.

3.4. Simulation performance evaluation

The metrics selected for the performance assessment is the LSP request blocking ratio. This gives an indication about the service availability. It is determined as the ratio between the amount of refused service requests from a CoS and the entire quantity of service requests of that CoS, therefore the QoS evaluation is done at the connection level. We can imagine that any call can only be rejected because of lack of resources, e.g. lack of capacity on the IP/MPLS domain or due to deficiency of wavelengths or ports on the optical domain.

4. Routing in integrated IP/MPLS over ASON/GMPLS multi-domain networks

The issue of routing in multi-domain multilayer optical networks has been not intensively investigated. Most of the studies have been focused on multilayer routing in IP/WDM networks have researched the routing issue in single domain networks [19]. Though some studies have addressed that issue, the authors in [19] have proposed a methodology addresses the problems of routing, connection setup and traffic grooming in IP/MPLS over ASON/GMPLS multi-domain networks. The planned methodology adapts a two level hierarchical routing methodology and use full mesh topology abstraction to advance routing scalability and reduce inter-domain blocking ratio; furthermore, the suggested method adapts a theme for traffic grooming in IP/WDM multi-domain networks to enhance the resources usage, yet this study did not pay attention to the DiffServ problem in optical multilayer multi-domain networks, furthermore the author did not address Inter-domain routing on the ASON/GMPLS optical domain, therefore Inter-domain routing was performed only on the IP/MPLS layer, therefore Optical-Electronic-Optical (OEO) conversion is a necessity at the border nodes, accordingly the application of DiffServ schemes mentioned above was not possible. In [20] the authors proposed an Inter-domain cross layer routing scheme for optical multilayer multi-domain networks that is able to establish service connections on both the IP/MPLS domain and ASON/GMPLS optical domain, which opens the gate to apply DiffServ schemes mentioned above. In this study we will extend this scheme proposed in [20] to adapt a routing methodology in IP/MPLS based ASON/GMPLS multi-domain networks that supports service differentiation by fulfilling the requirements for the previously mentioned three DiffServ schemes (RP-Diff, VT-HardDiff and VT-SofftDiff).

4.1. Hierarchical routing

Open Shortest Path First (OSPF) protocol adapted in MPLS and GMPLS uses link state protocol, each node communicates with other nodes by way of message flooding known as Link State Advertisements (LSA). This makes the entire network topology and the state of the links known by each router. Each node then autonomously computes the best next hop for every probable destination in the network. The computation of best next hops creates the routing table for the node. In this work we propose a multi-domain routing scheme, and for reasons explained above (security, scalability etc,…), some form of topology aggregation is required, therefore we introduce a tow level hierarchical routing scheme, accordingly and as hierarchical scheme suggest the designation of a specific border node in each domain as a Routing Area Leader (RAL) [3], we designate every border node as RAL, whereas each RAL has full routing information knowledge about its own domain network topology and the knowledge of the abstracted higher level topology, including the inter-domain links and the virtual links connecting Border Nodes (BN) in each domain, which created by the Full Mesh (FM) topology algorithm (see 4.2). This entity of FM Abstraction computes a DWDM topology abstraction for the domain by transforming the physical topology into an abstracted topology. This technology has been used for data/cell switching networks [16]. The abstracted state information is then flooded via inter-domain routing to all RAL in the entire network. This aims to maintain a synchronized global virtual view of the whole network. This abstracted information is then used to setup end-to-end inter-domain LSP.

4.2. Full-mesh (FM) abstraction

We use a FM abstraction algorithm has been proposed in [20] to create an abstracted FM topology of each domain; therefore we define the following notations, we will model the network as network is as a collection of domain D sub-graphs, G (V, L), where V are the physical nodes and L are the physical links. The full-mesh abstraction is invented to achieve intra-domain abstracted status. Explicitly, a domain G (V, L) is converted to a sub-graph encompassing the border nodes within a domain are connected via a fully meshed set of virtual links, therefore the number of available wavelength λ is calculated for all of these virtual links. The exact algorithm to compute the full mesh abstraction of a domain is shown in Figure 3, this algorithm loops between each BN pair (J, I) within a domain and computes the associated wavelength availability vector for the corresponding virtual link. The scheme first runs the open shortest path algorithm to find the available path between each border node pair, and then search this path for the available wavelengths by performing a sum operation on all the available wavelengths along the physical path found between each pair of border nodes.

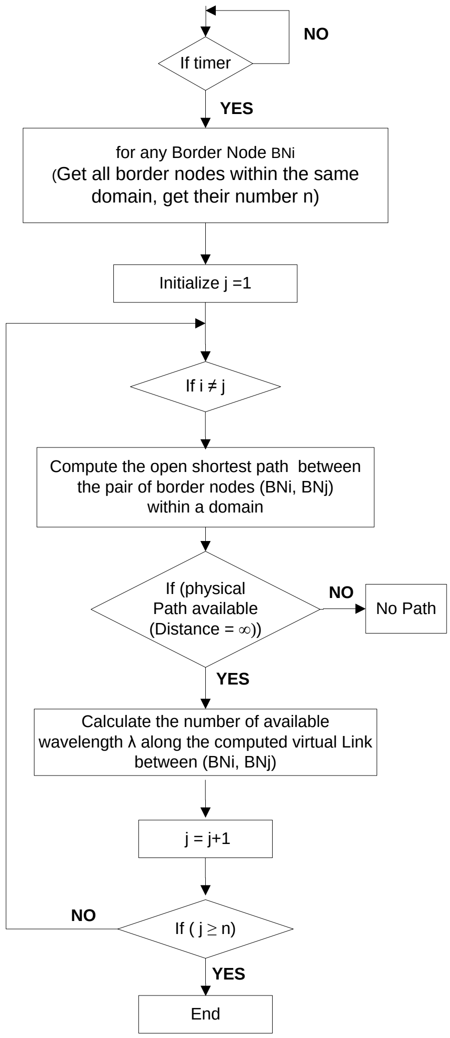

Figure 3: Full mesh topology abstraction algorithm

4.3. Inter-domain routing and connection setup

The projected scheme for inter-domain routing and connection setup (Inter-domain LSP setup) in this study uses the distributed Resource ReserVation Protocol- Traffic Engineering (RSVP-TE) [29] Loose Route (LR) signaling to perform the inter-domain path computation and setup sequence for an inter-domain connection (LSP) originating at an interior source node and destination node. The scheme uses OSPF-TE. The scheme to set up a new connection is presented in the following and illustrated in Figure 4. This exemplifies the calculation of an Inter-domain LR for a new LSP connection, which is performed using OSP algorithm, if source node has got a request for connection, it selects the adjacent border node and calculate the source domain route, and then the selected source domain border node calculates the shortest possible path as a domain sequence to the destination node. The enquired border nodes (RALs) then returns a LR series determines an end-to-end path to the target domain, e.g., egress border node at the source domain, all ingress/egress border nodes at intermediate domains, and last ingress border node at the target domain. This calculation is carried on over the virtual inter-domain topology graph (virtual Links) and physical inter-domain connections, whereas both are treated equally, (Note:

LR computation can be done locally, if the source node is also a border node). Finally, the destination domain border node computes the route to the destination node. Note: that for inter-domain LSP request for connection we consider all nodes are equipped with wavelength conversion capability; therefore, we do not care about wavelength assignment in this work.

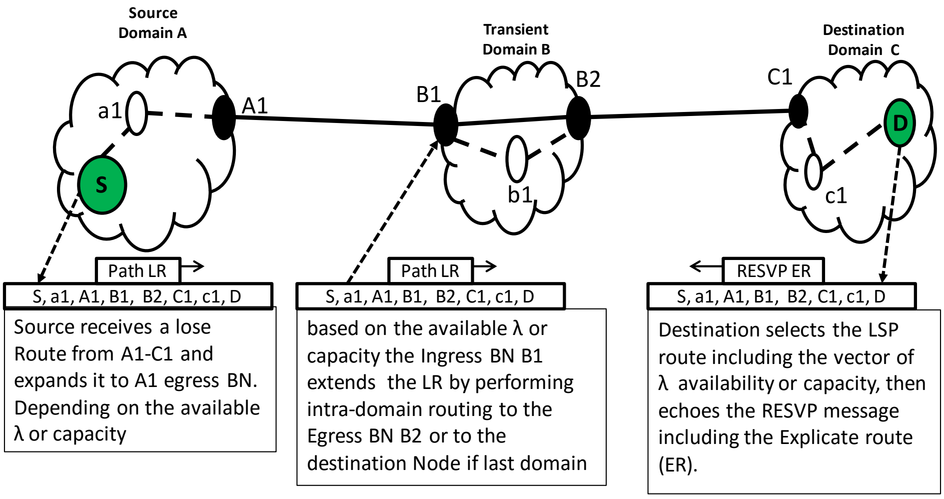

Figure 4: Inter-domain LSP setup

5. TE in IP/MPLS over ASON/GMPLS networks

In IP/MPLS over ASON/GMPLS network infrastructure, routing and TE can be performed in a multilayer mode. In an integrated IP/MPLS over ASON/GMPLS network, there are basically two multilayer routing policies, the Virtual Topology First (VTF) and the Physical Topology First (PTF) policies.

5.1. VTF policy

VTF policy attempts first to establish a new service request over the previously existing OLSPs. But if there is no sufficient bandwidth for new request for connection, a new OLSP creation is triggered. Consequently, VTF policy utilizes the accessible capacity as far as probable by aggregating sub-wavelength services on the present OLSPs. following is the list of procedures performed by the system:

1. Check if there is direct OLSP connecting source and destination nodes with sufficient capacity, and can accommodate the new request for connection. If yes go to step 4, else go to step 2.
2. Using a hop-based shortest path algorithm on the virtual topology, find if there is a series of available existing OLSPs connecting source and destination nodes. If a series exists go to step 4, else go to step 3.
3. Check if a new OLSP can be set up using a hop-based shortest path algorithm on the physical topology. If yes go to step 4, else go to step 5.
4. Accept the service request.
5. Reject the service request.

5.2. PTF policy

When using PTF policy to accommodate traffic, first the system tries to create a new direct OLSP that connects source and destination nodes. If it is not successful due to lack of physical resources (e.g. wavelengths and ports), the system tries to accommodate the traffic over the present virtual topology. PTF policy consumes as much as available physical resources producing a high physical resources expending (e.g. ports and wavelengths). The following list shows the actions performed by on PTF:

1. Appling hop-based shortest path algorithm to investigate if a new direct OLSP can be setup on the physical topology. If yes go to step 3, else go to step 2.
2. Using a hop-based shortest path algorithm on the virtual topology, check if there is a sequence of created OLSP that link source and destination nodes. If yes go to step 3, else go to step 4.
3. Accept the service request.
4. Reject the service request.

5.3. Evaluation of PTF and VTF policies

The effectiveness of an IP/MPLS over ASON/GMPLS network is noticeably affected by the selected routing policy [15, 30]. Resources optimization and the offered QoS are the utmost distinction factors between PTF and VTF. VTF has the better performs in terms of better resources usage as it establishes lesser number of OLSP, where PTF policy uses more physical for creating a higher number OLSP, where the capacity is less used doe to less aggregation of subwavelength services (grooming technique). The second point is that the PTF accommodates the traffic communication over direct OLSPs whereas VTF combines traffic on the previously present virtual topology. Consequently, it is more likely that the LSP created using VTF policy are transmitted on at least two OLSP. It has been illustrated the PTF policy reaches a fewer blocking ratio, compared to the VTF policy [30]. Moreover, the setting up of direct OLSPs avoids the probable bottlenecks that might be produced by electronic switching at intermediate nodes.

6. DiffServ in IP/MPLS over ASON/GMPLS multi-domain networks

For Service setup in Multi-domain networks, the routing requirements in multi-domain must be taken into account, the problems of security and scalability are well known. Under section 4 we proposed a hierarchical routing scheme adapting two levels of routing information based on FM topology abstraction algorithm to reflect only a limited amount of routing information among different domains. This routing information is the available number wavelengths λ to create a new OLSP connecting each pair of border nodes and the available capacity on it. The transport of a diversity of applications, which can have divers Quality of Service (QoS) necessities in IP/MPLS over ASON/GMPLS multi-domain implies the extending of distinguished Service pattern, which advances the QoS in pure IP networks, to the new underlying infrastructure. This implies the extension of our in section 4 proposed routing scheme to support DiffServ in IP/MPLS over ASON/GMPLS multi-domain networks, consequently we will adapt the techniques introduced in the introduction section to this paper and have been purposed in [21], (see 6.1, 6.2, 6.3) to analyze and evaluate their impact on the service differentiation in IP/MPLS over ASON/GMPLS multi-domain networks.

6.1. Routing policy differentiation service (RP-Diff)

The evaluation of both multilayer routing strategies shows that VTF is the better variation for saving physical resources while PTF is better in terms of meeting the needs for QoS. This suggests uniting both strategies to establish a DiffServ system in IP/MPLS over ASON/GMPLS networks. The RP-Diff arrangement is a simple procedure that is using the PTF policy to accommodate HP services, while LP traffic is transferred using the VTF policy. This was driven by the combination of both routing strategies VTF and PTF, which has shown that combining both strategies can produce a tradeoff between QoS and resource usage. The PTF policy deliver HP traffic with a higher grade of QoS, while VTF takes care of the absence of resource usage optimization neglected by PTF policy. This does not harm the HP services as the VTF policy is exclusively applied to LP traffic. Figure 5 in illustrates the blocking ratio when applying RP-Diff scheme. It demonstrates that there is no significant difference in effectuation in terms of blocking probability for both HP and LP traffic, which is illustrated in Both curves show the average blocking ratio, both carves overlap mostly. This is due to the fact that the PTF tries permanently to create OLSPs first and uses therefor the physical resources without using them resourcefully, which helps the VTF routing policy to find easily sufficient bandwidth available to establish new LSP link, on the previously created OLSPs by PTF routing policy.

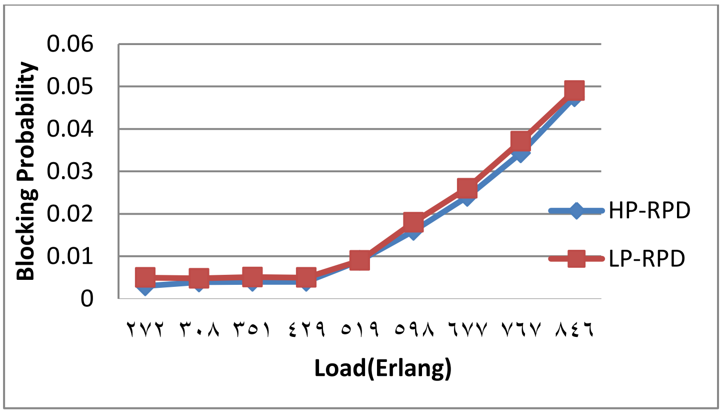

Figure 5: HP and LP traffic Blocking ratio by using in the RP-Diff policy

6.2. Virtual topology hard differentiation service (VT-HardDiff)

The VT-HardDiff procedure is a combination of the RPD of the RP-Diff procedure and the VTD method. Traffic of diverse CoS is transmitted onto different OLSPs. The CoS of the connection request has trigged the creation of a new OLSP will mark that OLSP with its identifier of the CoS, accordingly throughout its whole life cycle, the OLSP can exclusively be used to accommodate traffic of the CoS, which has triggered its creation. This means that VT-HardDiff operates an OLSP distinction that does not permit virtual topology resources sharing between services belonging to diverse CoS. The fact that in an IP/MPLS over ASON/GMPLS network permits an operator to create numerous different virtual topologies has motivated the VT-HardDiff scheme, whereas every virtual topology is assigned to the conveyance of one CoS, the diverse virtual topologies can be considered independent from each other, consequently can transmit traffic of diverse QoSs without the necessity to utilize the same resources jointly. Figure 6 illustrates the blocking ratio when applying VT-HardDiff, it shows clearly that the VT-Hard-Diff approach produces blocking ratio variance between HP and LP traffic. Distinct from the RP-Diff policy, the two curves illustrating the HP and LP blocking ratios while using the VT-HardDiff policy all permanently far apart. This outcome is a result of the fact that the VTD apply the VTF policy, and as RP-HardDiff imply that LP traffic will be routed on its own LP virtual topology. These facts have less bandwidth accessible to establish traffic via groom technique. In addition, the LPT is not well connected in comparison to HPT due to the lesser amount of established OLSPs, based on the fact that LPT uses VTF to establish the traffic. In addition to that, the VTF policy has not sufficient physical resources available when required to create a new OLSP, which is due to the greedy physical resources usage of PTF. This is because the physical resources are not distributed between both routing policies and/or priorities; it can be used similarly by both HP or LP traffic once required.

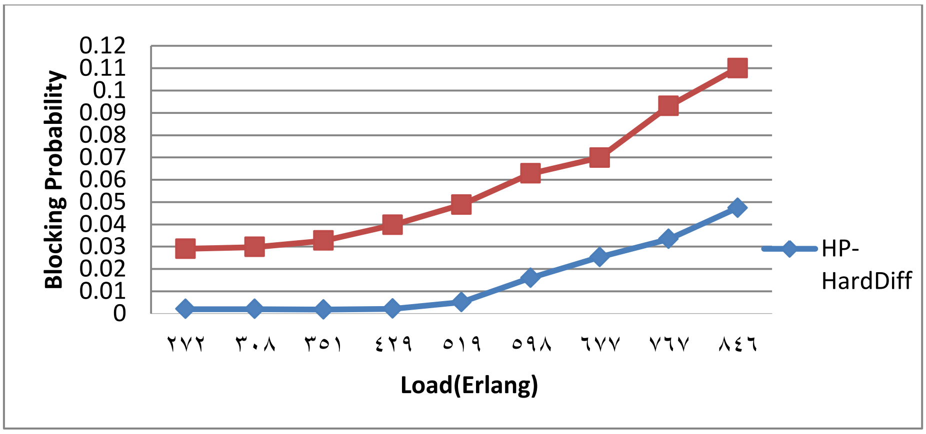

Figure 6: HP and LP traffic Blocking ratio in the VT-HardDiff policy

Though we have achieved our goal to establish QoS differentiation, the VT-HardDiff did not improve significantly the routing outcome compared to the RP-Diff, even the opposite is to see in the figures 4 and 5. We cannot determine any really improvement in the blocking ratio of HP traffic, which using PTF routing policy, whereas the blocking ration of the LP traffic is getting worst, which shows that VT-HardDiff policy worsens the output compared to the RP-Diff scheme. This is because of the routing policies applied for both HP and LP traffic PTF and VTF, for the reasons explained above. This performance of the HardDiff schemes implies some kind of sharing an amount of resources between the HP and LP traffic to overcome this problem. This can be done by sharing an amount of capacity between the two virtual topologies. This has resulted in a new DiffServ approach explained bellow under 6.3.

6.3. Virtual topology soft differentiation service (VT-SoftDiff)

The VT-SoftDiff scheme is combination of all policies (RPD, VTD and VTS). The VTS performance permits HPT and LPT to share a slight quantity of resources. A small modification of the VTF policy in LPT enables the bandwidth sharing between HPT and LPT. The modification is considering only the search for a direct OLSP from start to target for a new LP LSP demand, whereas for this case the system does not differentiate between the HP-OLSPs and the LP-OLSPs. In other words, the LPT can use the bandwidth assigned exclusively to the HPT if there is a direct OLSP linking the source node and target node of the new LSP request for link. This is allowed in VT-SoftDiff only for LPT; HPT cannot take advantage of this modification. This means that the LPT can accommodate its traffic on HP direct OLSP but not vice versa. There are two motivations for this decision. The first one is that the LPT can be more instable as the operators may need to reconfigure the LPT many times more than the HPT. This would make HP services undergo instability when accommodate HP services on LPT and therefore lower QoS. The second motivation is the use of VTF for accommodating LP traffic in VT-HardDiff method, which limit the available capacity for the LP traffic. The proposed bandwidth sharing only happened on OLSPs directly linking source node and destination node (i.e. LSPs created only on one OLSP). This was driven by the fact that the scheme uses the VTF routing strategy to put up LP traffic and consequently LP LSPs will merely be putted up on multi-OLSP links. If that would happen on HPT, these multi-OLSP links would use extend the amount of bandwidth utilized by the LP traffic. Therefore, considering exclusively OLSPs directly linking source node and target node will reduce the capacity consumed by the HPT without reducing its service. Figure 7 shows the blocking ratio achieved if applying VT-SoftDiff, the results show significant improvement in performance regarding the HP traffic as the blocking ratio stays low even by higher traffic load, also in performance regarding the LP traffic is better than VT-HardDiff but only by higher traffic load. The explanation for that is the capacity sharing between both traffic priorities, which allows VTF to accommodate traffic on direct lightpath soften the stress on the physical topology, which make more physical resources available for the HPT routed using PTF routing policy.

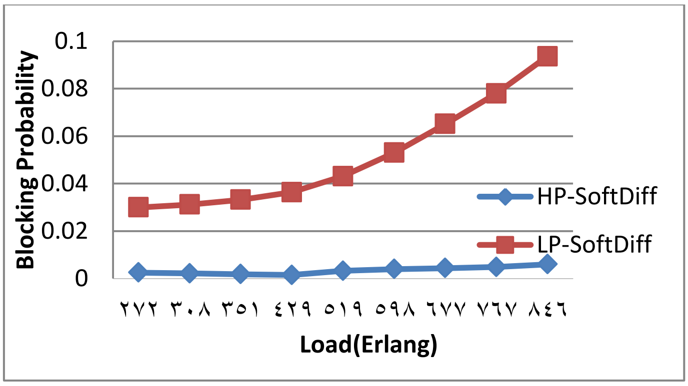

Figure 7: HP and LP traffic blocking ratio by using VT-SoftDiff policy

Figure 8 gives an over view of all three tested DiffServ approaches, it demonstrates clearly that by small and middle data traffic load until 429 Erlang in network, compared to the RP-Diff, a slight improvement is observed within the same load when SoftDiff is applied, this is because the greedy usage of Physical resources when applying PTF, whereas the created OLSP will stay classified as HP-VT, additionally the limited resources sharing between the HP-traffic and LP-traffic allow VTF to accommodate traffic on direct lightpaths, which softens the stress on the physical topology and provide the HP-traffic with more physical resources.

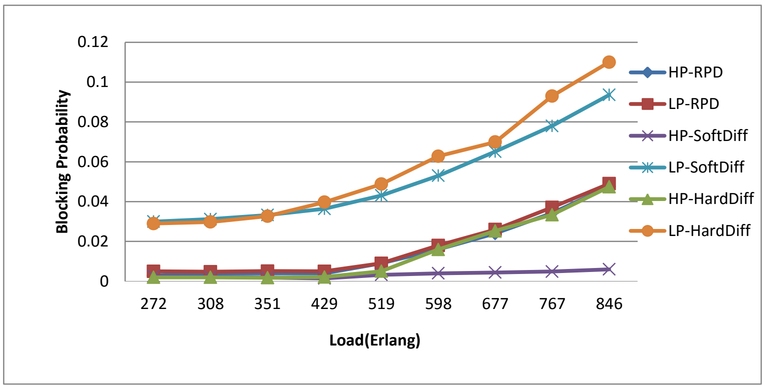

Figure 8: HP and LP traffic blocking ratio by using RP-Diff, VT-HardDiff and VT-SoftDiff policies

The advantages of the VT-SoftDiff approach are clearer for higher traffic load, once the traffic load goes above 519 Erlang, then the HP-traffic blocking ratio stays insignificant small. In the meantime, the blocking ratio continues to increase if applying the RP-Diff DiffServ policy; this allows the network operator to transmit more HP-traffic under heavy traffic load while keeping its blocking ratio in acceptable range.

7. Conclusions

In this paper we addressed the problem of service differentiation in multi-domain multi-layer optical IP/MPLS over ASON/GMPLS networks; therefore, we used both known routing policies in IP/MPLS over ASON/GMPLS multilayer networks, which are PTF and VTF. Applying these routing policies in optical multi-domain networks request the invention of a hierarchical routing approach to keep the restrictions requested for routing in multi-domain networks. In this study we use a hierarchical routing scheme along with physical topology abstraction algorithm, which makes the application of the PTF and VTF policies multilayer multi-domain networks possible. Then we have tested and evaluated the performance of that in related work proposed DiffServ schemes while applying them in multilayer multi-domain optical networks. The results have shown clearly that the VT-SoftDiff has the best performance regarding blocking ratio for HPT and DiffServ in general. Compared with both other policy, as creating service differentiation is not enough if it is not combined with performance improvement, therefore the RP-HardDiff is not really an option when applying DiffServ in IP/MPLS based ASON/GMPLS multi-domain networks. In this study we evaluated the performance of the three DiffServ schemes based on the blocking ratio, which is defined as the class of services (CoS), to evaluate the quality of service after the establishment of a LSP service connection, we must also consider the packet delay, lost…etc. this will be in the scoop of our future work.

References

[1] Chan, V.: Near term future of the optical network in question?. IEEE J. Sel. Areas Commun. 25(9), 1-2 (2007)

[2] Liu, Q., Kok, M., Ghani, N., Gumaste, A., Hierarchical routing in multi-domain optical networks in: Computer Communications, Academic Press,2006, volume 30, pp 122-131.

[3] G. Bernstein, B. Rajagopalan, D. Saha, Optical Network Control-Architecture, Protocols and

Standards, Addison Wesley, Boston, 2003.

[4] Mannie, E., et al.: Generalized multi-protocol label switching (GMPLS) architecture, RFC 3945 (2004)

[5] Mohan, G., et al.: QoS routing in GMPLS-capable integrated IP/WDM networks with router cost constraints. Comp. Commun. 31(1), 19-34 (2008)

[6] Colitti W, Steenhaut K, Colle D, et al. Integrated routing in GMPLS-based IP/WDM networks. Photonic Network Communications. 2010.

[7] Pasqualini, S., et al.: Inuence of GMPLS on network providers' operational expenditures: a quantitative study. IEEE Commun.Mag. 43(7), 28-34 (2005)

[8] Gabeiras J.E., et al.: Is multilayer networking feasible? Opt. Switch. Netw. 6(2), 129{140 (2009)

[9] Puype, B., et al.: Inuence of multilayer tra_c engineering timing parameters on network performance. In: Proceedings of IEEE International Conference on Communications (ICC), Istanbul, Turkey, pp. 2805-2810 (2006)

[10] Oki, E., et al.: Dynamic multilayer routing schemes in GMPLS based IP+optical networks. IEEE Commun. Mag. 43(1), 108-114 (2005)

[11] Yan Q., et al.: Performance evaluation of multi-layer tra_c engineering enabled IP-over-ION networks. Photon. Netw. Commun.9(3), 255{280 (2005)

[12] Evans, J., et al.: Deploying Di_Serv at the network edge for tight SLAs, Part I. IEEE Internet Comput. 8(1), 61-65 (2004)

[13] Jemili, I., et al.: Integration of Di_Serv over MPLS: an improved quality of service architecture. In: Proceedings of ACS/IEEE International Conference on Computer Systems and Applications (2003)

[14] Iovanna, P., et al.: Performance analysis of a tra_c engineering solution for multilayer networks based on the GMPLS paradigm. IEEE J. Sel. Areas Commun. 22(9), 1731-1740 (2004)

[15] Comellas, J., et al.: Integrated IP/WDM routing in GMPLS-based optical networks. IEEE Netw. 17(2), 22-27 (2003)

[16] Iliadis, Optimal PNNI complex node representations for restrictive costs and minimal path computation time, IEEE/ACM Transactions on Networking 8 (4) (2000)

[17] X. Bruin et al., Hierarchical Routing With QoS Constraints in Optical Transport Networks, 3rd IFIP-TC6 Networking Conference, Athens, Greece, May 2004.

[18] Q. Liu et al., \Hierarchical Inter-Domain Routing in Optical DWDM Networks", IEEE INFOCOM 2006 High-Speed Networking Workshop, Barcelona, Spain, April 2006.

[19] Halabi W, Steenhaut K, Goossens M, Truong T-H, Now_e A. Hierarchical routing and tra_c grooming in IP/MPLS-based ASON/GMPLS multi-domain networks. Photonic Network Communications. 2011. Available at: http://www.springerlink.com/index/10.1007/s11107-011-0352-9. June 2012, Volume 23, Issue 3, pp 217-229.

[20] Halabi W, Steenhaut K, Goossens M, Applying PTF/VTF routing policies in Multilayer IP/MPLS based ASON/GMPLS multidomain networks. Photonic Network Communications. Available at: https://link.springer.com/article/10.1007/s11107-012-0387-6. February 2013, Volume 25, Issue 1, pp 24-34

[21] Colitti W, Steenhaut K, Gurzì P, et al. Service differentiation in IP/MPLS over ASON/GMPLS networks. Photonic Network Communications. 2009;19(3):301-310. Available at:

http://www.springerlink.com/index/10.1007/s11107-009-0235-5. Accessed November 19, 2010.

[22] Saradhi C, Ramamurthy B, Schupke D, Oki E. Guest editorial - Multidomain optical networks: issues and challenges. IEEE Communications Magazine. 2008;46(6):76-77

[23] Szymanski, A., et al.: Grade-of-service-based routing in optical networks. IEEE Commun. Mag. 45(2), 82-87 (2007).

[24] Golmie, N., et al.: A di_erentiated optical services model for WDM networks. IEEE Commun. Mag. 38(2), 68-73 (2000)

[25] Wei,W., et al.:Di_erentiated integratedQoS control in the optical internet. IEEE Opt. Commun. 42(11), 27-34 (2004)

[26] Puype, B., et al.: Multilayer traffic engineering for multiservice environments, Photon. Netw. Commun. 18(2), 150-159 (2008)

[27] Puype, B., et al.: Optical cost metrics in multi-layer traffic engineering for IP-over-optical networks. In: Proceedings of 6th International Conference on Transparent Optical Networks, Wroclaw, Poland, vol. 1, pp. 75-80 (2004)

[28] OMNET++ version 4.0 user manual, available online at http://www.omnetpp.org/doc/manual/usman.html

[29] Berger L. – "eneralized Multi-Protocol Label Switching (GMPLS) Signaling Resource ReserVation Protocol-Traffic Engineering (RSVP-TE) Extensions'' - IETF RFC 3473, January 2003

[30] Colitti, W., et al.: Adaptive multilayer routing in the next generation GMPLS Internet. In: Proceedings of the Second Workshop on Intelligent Networks: Adaptation, Communication and Reconffiguration (IAMCOM), Bangalore, India, pp. 768-775 (2008)

Author Biography

Dr. Eng. Wajdi Halabi has received his PhD from Vrije Universiteit Brussels (VUB), Department of Electronics and Informatics (ETRO), Brussels/Belgium in December-2012, his Master in in Computer Science Engineering from University of Applied Science in Bochum- Germany in February-2005, and his High Diploma in Telecommunication Engineering from University of Applied Science in Karlsruhe/Germany in February-2002. Dr. Halabi has received the Erasmus-Mundus External Cooperation Window (ECW) scholarship and became in April-2009 a PhD researcher at the Electronics and Informatics department (ETRO) of Vrije Universiteit Brussel (VUB). His PhD entitled "Design of New Routing Algorithm for optical Multi-Domain Networks". His research activity focuses on IP/WDM and IP/MPLS based ASON/GMPLS optical multi-domain networks including Multilayer Traffic Engineering (MTE). Dr. Halabi was a Lecturer from October 2005 till 2012 and became an assistant Professor in January-2013 at the University College of Science and technology (UCST)-Khanyunis in Gaza strip, Palestine.