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GMPLS LSP SETUP AND RESTORATION USING ODU PATH LATENCY CRITERIA

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ABSTRACT

The current generation 5G and ultra-high-speed networks have strict requirements of low latency performance from the transmission network. Proposed herein is a mechanism to ensure that a Generalized Multiprotocol Label Switching (GMPLS) Optical Transport Network (OTN)-based transport network considers latency as one of the criteria to establish and reroute OTN Optical Channel Data Unit (ODU) Label Switched Path (LSP) circuits. This will ensure that clients receive the ODU path with latency criteria that satisfy the clients' specified acceptable limits.

DETAILED DESCRIPTION

International Telecommunications Union Telecommunication Standardization Sector (ITU-T) Recommendation G.709 is a standard for communicating data over an optical network. G.709 OTN-based transport networks serve as "digital wrappers" for a variety of client payloads types such as synchronous optical networking and synchronous digital hierarchy (SONET/SDH) legacy customer services, Ethernet services, and fiber channel services. Currently, various OTN data rates (e.g., OTU-1, OTU-2, OTU-3, OTU-4, and OTUCn) and various granularities (ranging from ODU-0 to ODUCn) exist and are used to transport various client services such as Ethernet services of 1GIGE, 10GIGE, 40GIGE, 100GIGE and/or Fiber Channel services FC1G, FC2G, FC4G, FC8G, FC16G, ESCON protocol flavors, in addition to the various other legacy SONET/SDH services. Each of these client types has a strict transmission performance requirement on the OTN network. The primary performance parameters that typically impact a network's performance are bit error rate (BER) and end-to-end latency values. With the introduction of highspeed services and Fifth Generation (5G) mobile networking technology, the transmission network latency has become an important critical benchmark of network performance. Thus, low latency has become a significant network performance objective.

Further, each of the above-listed client types requires a different set of performance objectives from the service provider network. Some client applications, such as File Transfer Protocol (FTP), are sensitive to error but can handle relatively low latencies, whereas other applications, such as telephonic voice communications, are very sensitive to latency such that excess latency will render the service unusable. As another example, video transmission is sensitive to both bit errors and latency.

OTN-based networks may have support for bit error monitoring that is similar to that used in SONET/SDH standards. In addition, OTN-based networks also support a Tandem Connection Monitoring (TCM) bit error monitoring function useful for monitoring across multi-domain networks. Forward error correction (FEC) techniques support both error detection and correction. One key driver for a low latency requirement is high-frequency trading applications. For such applications, a few milliseconds of latency can impact a transaction. Financial or other trading companies are very focused on end-to-end private pipeline latency optimizations that improve latency by even a few milliseconds. Latency is thus one of the key parameters that these customers consider when selecting a private pipeline provider. Other key applications, like video gaming, conferencing and storage area networks, also require stringent latency and bandwidth.

Currently, GMPLS creation or restoration addresses four types of end-to-end LSP recovery for OTN networks: 1:1 (unidirectional/bidirectional) protection, 1:N (N >= 1) LSP protection with extra-traffic support, pre-planned LSP rerouting without extra-traffic (including shared mesh), and full LSP rerouting. These four types of creation or restoration schemes do not consider OTN path latency/delay as a parameter during creation or restoration of an LSP circuit. When path latency is not considered during ODU LSP creation or restoration, the network operator can experience latency issues.

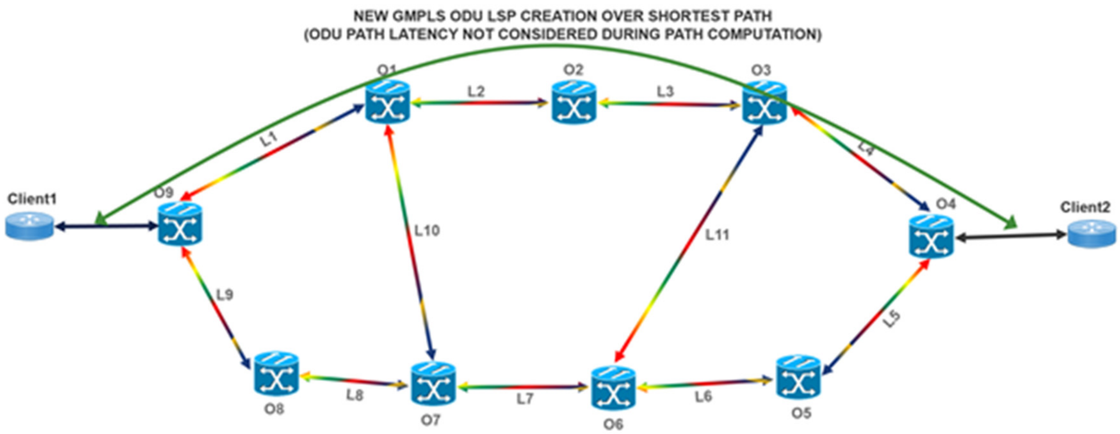

Figure 1

Figure 1 depicts an example in which ODU path latency is not considered during path computation. For example, when a new ODU LSP circuit creation is performed for a client service, this new LSP may be created based on some variant of Dijkstra's Shortest Path First algorithm. However, the end-to-end ODU path latency on this LSP path is not taken into consideration. Failure to consider the ODU path latency for the service could lead to latency values not meeting the target service application’s delay requirements. Thus, traffic will not flow as expected with respect to latency. In the example depicted in Figure 1, an ODU LSP is established between Client1 and Client2. However, in conventional approaches, the shortest path computations do not take into account ODU LSP path latency, and therefore, the path latency remains unknown until a client determines its own end-to-end latency.

OTN ODU LSPs are typically implemented in a dense wavelength division multiplexing (DWDM)-linked backbone network. A running ODU LSP path with a specific latency value might experience a change in latency when the same circuit switches to an alternate DWDM path. This rerouting will cause the ODU LSP latency value to change on-the-fly since the DWDM path may become longer due to the DWDM wavelength switched optical network (WSON) circuit being restored on a longer DWDM path. Hence, if the latency increases on-the-fly, it will trigger unpredictable latency outcomes for client services.

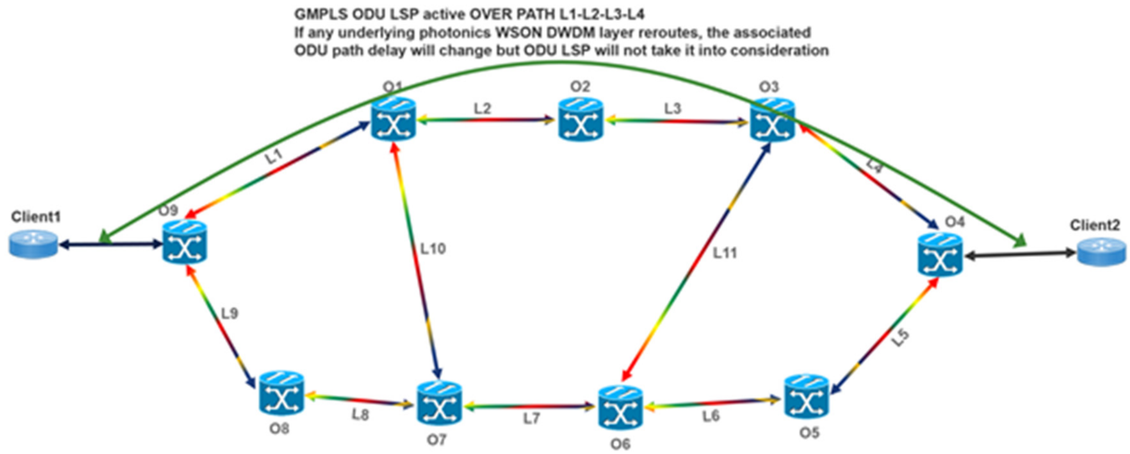

Figure 2

Figure 2 depicts an example of ODU path delay resulting from DWDM rerouting. As depicted, the GMPLS reroute does not take latency into consideration when computing a reroute. Thus, conventional implementations on OTN GMPLS creation and restoration do not address the ODU LSP setup or recovery based on path latency/delay values.

Accordingly, a solution is presented herein that considers latency as one of the criteria in an SPF algorithm used for path computation when creating a new LSP. Similarly, a mechanism is proposed that uses latency as a reroute criteria. The LSP OTN path delay can be directly computed using methods described in ITU-T G.709 (using ODU-k overhead bytes PM and TCM field values).

First, ODU path latency is considered during LSP creation. On receiving a new LSP setup request, a GMPLS stack will use its existing Shortest Path Algorithm and will provide a list "LIST-N" of N shortest paths. These shortest paths will be evaluated based on either link metrics or other design choices. Out of the N unique shortest paths, the current method will run only on a predetermined number of paths, such as the first three paths in the list. However, in other embodiments, this depth of path list (e.g., beyond the first three) can be made user-configurable.

Beginning with the first path listed in "LIST-N", the head node triggers creation of a network-to-network interface (NNI)-to-NNI, end-to-end LSP test-path. This LSP test-path will be leveraged to compute this current path latency and thus serves as a temporary provision. Once this LSP test-path circuit is established, operational TCM is enabled on this path at the end points. The system then uses the TCM bytes to automatically calculate the path latency for this present LSP test-path using associated TCM DMt overhead field values as outlined in the ITU-T G.709 standard.

Once the latency value for the LSP test-path is available, the LSP test-path is removed. Alternatively, a user-configurable parameter for an acceptable latency value can be provided for this LSP. This parameter can be defined during the LSP's setup phase. In particular, the "current latency value" can be compared with the acceptable latency value to establish the LSP only if the current latency value is better than the acceptable latency value. If the first path has worst latency than the acceptable latency value, then the second path listed in "LIST-N" can be selected, and the same set of steps can be performed to determine the path's usability. The same set of actions can be repeated on all the candidate paths. Thus, this approach ensures that the LSP path that is selected to carry client traffic satisfies the "acceptable latency value" defined or proposed by a client in advance before the LSP begins carrying real client traffic payload.

Additionally, ODU path latency is considered during LSP restoration. The LSP restoration process is mostly similar to the creation process. First, latency for a new path is considered for LSP restoration based on the active path fiber cut. For example, the LSP may be active on a given path in which one of the links experiences a catastrophic fiber cut, thus necessitating a LSP reroute. The LSP reroute mechanism that is employed may be the same as the approach used in the LSP setup process. A precomputed backup path can be used with acceptable latency value.

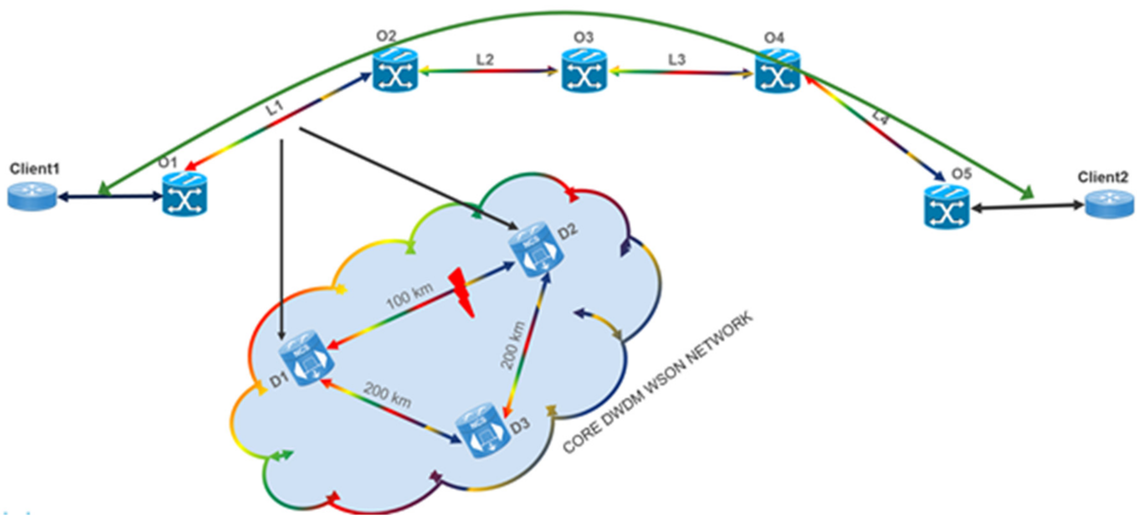

Figure 3

Figure 3 depicts an example of LSP rerouting that can be triggered when latency increases outside of a predefined limit on-the-fly. In the depicted example, client traffic has an LSP established on Service Provider OTN network nodes O1, O2, O3, O4 and O5 having GMPLS OTN LSP. OTN links on the working LSP path are L1, L2, L3, and L4. In the example, Link L1 has an underlying DWDM WSON path between core DWDM nodes D1 and D2, which have a path length of 100 km. Initially, the working LSP path has latency values that are within an acceptable latency limit. When the short path on DWDM between D1 and D2 (100km) encounters a catastrophic fiber failure, the DWDM path is restored to the longer DWDM path via D3 (D1 to D3 and D3 to D2), and the new core DWDM span length is now changed from the original 100 km to a longer 200 + 200 = 400 km path. When the fiber cut occurs on the short DWDM path, the OTN LSP restores as per the new design on a new path which again has a latency value within an acceptable latency limit parameter for the current LSP.

However, when this LSP is reverted, and the revert timer expires, the LSP will again attempt to revert to the original home path (over L1-L2-L3-L4) which has a new changed latency (due to the longer DWDM path in use). Thus, the approach presented herein performs latency checks on LSP revert as well. A given LSP shall revert to its original home path only after it evaluates the latency on the original home path and determines that the latency satisfies the acceptable latency limit parameter for the current LSP.