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Adaptive Network Manager: Coordinating operations in flex-grid networks

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ABSTRACT

Transport networks provide reliable delivery of data between two end points. Today's most advanced transport networks are based on Wavelength Switching Optical Networks (WSON) and offer connections of 10Gbps up to 100Gbps. However, a significant disadvantage of WSON is the rigid bandwidth granularity because only single, large chunks of bandwidth can be assigned matching the available fixed wavelengths resulting in considerable waste of network resources. Elastic Optical Networks (EON) provides spectrum-efficient and scalable transport by introducing flexible granular grooming in the optical frequency domain. EON provides arbitrary contiguous concatenation of optical spectrum that allows creation of custom-sized bandwidth. The allocation is performed according to the traffic volume or user request in a highly spectrum-efficient and scalable manner.

The Adaptive Network Manager (ANM) concept appears as a necessity for operators to dynamically configure their infrastructure based on user requirements and network conditions. This work introduces the ANM and defines ANM use cases, and its requirements, and proposes an architecture for ANM that is aligned with solutions being developed by the industry.

Keywords: Elastic optical networks, control plane, network automation, multi-layer.

1. INTRODUCTION

Transport networks provide reliable delivery of data between two end points. Elastic Optical Networks (EON) provides spectrum-efficient and scalable transport by introducing flexible granular grooming in the optical frequency domain [1]. EON provides arbitrary contiguous concatenation of optical spectrum that allows creation of custom-sized bandwidth. This bandwidth is defined in slots of 12,5GHz. EON allows allocating appropriate-sized, as opposed to fixed-sized, optical bandwidth to an end-to-end optical path. The allocation is performed according to the traffic volume or user request in a highly spectrum-efficient and scalable manner.

The existing transport network architectures were conceived and designed having in mind both the characteristics and the traffic demands of the classic services (e.g. Internet access or VPNs), which are predictable. Traditional carriers' networks operation is very complex and is neither readily adaptable nor programmable to flexible traffic requirements. Multiple manual configuration actions are needed in metro and core network nodes (e.g. hundreds of thousands of nodes configurations per year in mid-size network operators). Furthermore, network solutions from different vendors typically use vendor-specific Network Management System (NMS) implementations. Such complex architecture (depicted in Figure 1) derives in complex and long workflows for network provisioning (e.g. up to two weeks for Internet service provisioning and more than six weeks for core routers connectivity services over photonic mesh).

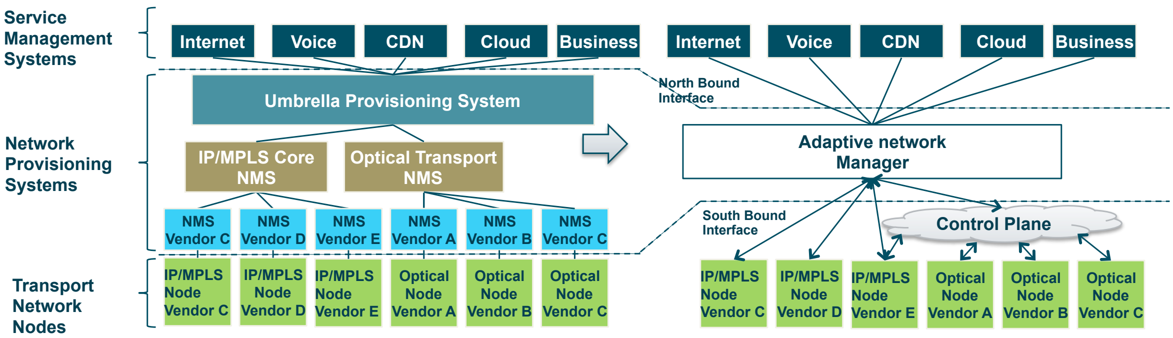

Figure 1: Evolution towards an Adaptive Network Manager.

There is a number of problems with the current transport network provisioning approach. First, the interfaces between the service management systems and the umbrella provisioning system are typically proprietary, non-programmable and closed interfaces that prevent new applications from a rapid and automated introduction. Second, the orchestration capabilities across different NMSes (e.g., IP/MPLS NMS and Optical Transport NMS) are very difficult to achieve as each NMS is a highly specialized vendor element that lacks interoperability with other vendors' elements especially on the NMS to NMS communication. Third, there is little standardization on interface for upper layer applications or services. With the current approach, it is not easy to provide an abstracted topology view or service-specific view of the network to the application in a fairly generic fashion, or to allow application to request and/or control virtual network resources.

ANM proposed in IDEALIST project should improve provisioning process of legacy NMSs (Figure 1). Current approach does not allow a common interface to support deploying multiple services. ANM architecture would require a network-service interface, which is a common standard interface for multiservice provisioning. On the other hand, NMS has multiple vendor-specific interfaces, which creates great problems in terms of tools integration. ANM would use standard network configuration interfaces, which will trigger automated standard control plane for multidomain/vendor/layer operation. Key building blocks of such unified network provisioning architecture are: (1) network elements interface must be standard, (2) service layer and network coordination is required, (3) common Network-Service interface enabling a common entry point to provision multiple services.

ANM enables the dynamic and automated control of server layer (EON) transport resources. However, based on Figure 1, ANM looks like a black box with multiple functionalities inside of it. Within IDEALIST project, the architecture of ANM will be defined and standardized in multiple boxes with defined standard interfaces.

2. ADAPTIVE NETWORK MANAGER

Adaptive Network Manager (ANM) monitors network resources, and decides the optimal network configuration based on the status, bandwidth availability and user service. It is important that an ANM provides a set of standard interfaces, which facilitates communication with other network elements and key network components. These components include the Operation Support Systems (OSS), Network Management Systems (NMS) or Path Computation Elements (PCE), to provide additional capabilities, including automated network configuration and resource optimization. The main task of ANM is to coordinate, or orchestrate, network procedures based on received requests. ANM starts processes after receiving triggers from the operator via NMS, failures, measurements or periodical requests. After a trigger is received, ANM process it and starts a workflow or queues it for later analysis. Once a workflow is run, ANM can return the answer to the operator so network configuration can be accepted, rejected or modified. There are other workflows that do not require human involvement. Finally, ANM can be focus just on elastic optical networks or it can take into account the impact of client layers like IP/MPLS. Table 1 shows a classification for the different scenarios where ANM operates.

Triggers	Processing Triggers	Human involvement	Network Scope
Human	Start process	Automatic Configuration	Single Layer
Failure	Queue for correlation	User Assisted Configuration	Multi Layer
Measurement			
Periodic			

Table 1: Classification for the different ANM scenarios

3. USE CASES

3.1 Automatic IP Link provisioning

The first use case describes how the ANM framework can be applied to the provisioning of an IP link between two routers. In this example, the photonic meshed network is composed of (elastic) ROADMs providing connectivity to several IP routers.

IP link provisioning is a basic operation done by network operators. This operation is used to provide customer services, including Internet connectivity, VPN or IPTV. When operators deploy additional capacity, new IP link equipment may be installed in the network. This process typically requires manual intervention and is scheduled and deployed periodically. Once equipment is installed in the network and operator receives a request to create a new IP link between two locations, there is a dialog between the IP and transport department to complete the configuration of both layers. This configuration process may take days to complete, even when network elements are already set-up in the network. ANM is intended to automate the configuration process, and in specific cases dynamically, by utilizing control plane technologies, and using an interface to configure IP routers (like OpenFlow or NetConf) to configure individual network elements. Also, the optical layer can be directly configured from the router using either User Network Interface (UNI) or PCE Protocol (PCEP) to trigger control plane mechanisms [6].

3.2 Dynamic Bandwidth Allocation based on traffic changes

Current network provisioning of packets over circuits is done in a static manner. Network operators are willing to provide services to end-users (Internet access, VPN, etc.). In aggregation networks, traffic from multiple sources is multiplexed so large traffic streams are sent to backbone networks. There are monitoring probes in the network, which provide periodical information to network operators, but modifications of circuits is not done. Typically new connections are created yearly or at specific time intervals (six months) in the network.

ANM can deal with this dynamic information and decide on the bandwidth adaptation of the connections thanks to the elasticity of BVT. ANM requires retrieve information from routers (such as SNMP) or monitoring probes depending on the traffic patterns in the network. Based on this information, ANM would decide modifications in the parameters of the connections and apply changes to the configuration of the router or BVT. This use case is shown in Figure 2.

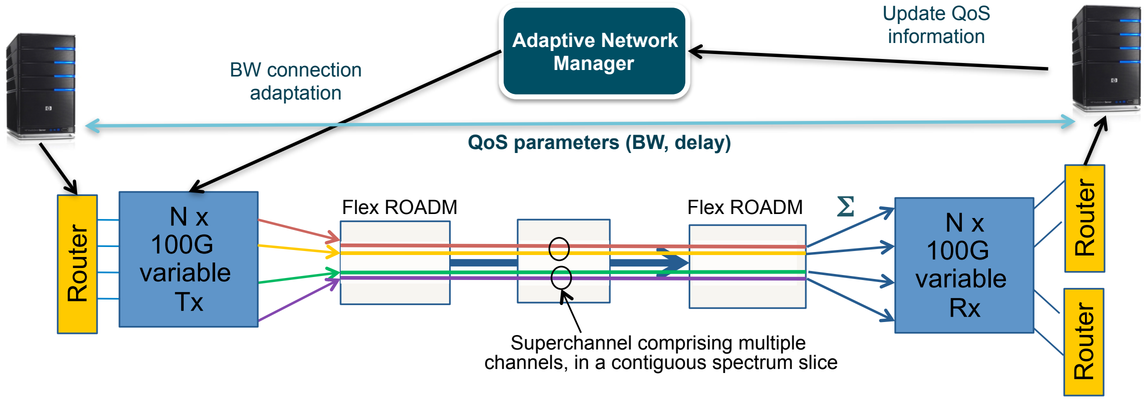

Figure 2: Example scenario for dynamic bandwidth allocation use case

Previous example focused on the parameter modification of an already established link. Another scenario is the case of the creation of a by-pass link when all the existing bandwidth on an intermediate link between two routers has already been entirely used up (or crosses a pre-defined threshold). Based on monitoring information, ANM would start an Automated IP Link Provisioning workflow as defined in previous section. If there are Sliceable BVTs (SBVT) in the network, ANM can split the interface's bandwidth in two (or more) fragments, reducing the bandwidth of the original connection (the one to the next IP hop) and using the new available bandwidth for a new direct connection to the destination router.

3.3 Periodic defragmentation to improve bandwidth allocation

The reoptimization (defragmentation) process is roughly defined as the process by which an ANM affects the state of currently active connections in the network by changing some of their attributes. Such attributes typically correspond to the actual reserved resources and changing them may involve, for example, shifting the nominal central frequency of the frequency slot allocated to a connection and/or adjusting its allocated frequency slot width (i.e., due to a change of modulation formats or bitrate) or even the physical routes that were assigned to the connections during path computation. In general, the main purpose of the reoptimization process is to improve the utilization of the network resources, since the main observable result is a sub-optimal throughput. This process can be triggered either manually by a network operator or based on automated maintenance process.

3.4 Network reoptimization after network failure recovery

In optical transport networks, operators are commonly required to deploy some form of resilience when transporting client data. Such resilience can be implemented by means of either dynamic restoration of failed connections (i.e., a new path is computed and established after a failure is localized) or dedicated/shared protection by establishing at the same time, e.g., for a given traffic demand, the corresponding working and backup paths.

In both cases, if network connections are flagged with elasticity (i.e., their properties and attributes can be dynamically adjusted) of the physical path, bitrate or modulation format, such elasticity can be exploited to improve the network survivability by dynamically adapting those attributes to the network state. As there are dynamic control plane mechanisms, which run after each failure, they can lead to an inefficient network configuration. Hence, after multiple failures, ANM can check using an algorithm in a PCE or an external tool if current network configuration is optimal or not. Based on this information, ANM can alert operator, who decide if this new configuration should be loaded in the network.

3.5 Multi-layer restoration

Multi-layer restoration is the process of restoring a fail of any element in the IP/MPLS or optical layer between two client nodes in a coordinated manner. Unlike single layer restoration (i.e., pure optical restoration), the multi-layer restoration process involves the negotiation of the best possible path properties between the optical layer and the IP/MPLS layer, given a failure in the network. There are two scenarios where coordination is beneficial: failure in the optical layer or failure in the IP/MPLS layer.

Existing approaches to optical restoration do not focus on the constraints that must be met for the restoration path. Often these approaches implicitly assume that any viable restoration path is good. This is not a valid assumption in the event the failure takes a long time to repair since the client layer must return to a relatively normal state. Therefore the most optimal approach is to allow the client to define different constraints for the restoration path versus the constraints that have been defined for the working path. With this negotiation between layers, it is possible to dynamically adapt to the requirements of the client layer.

The second scenario where multi-layer restoration can be interesting is when there is a failure in the IP layer. In case there is a failure on a router, ANM can look for a candidate back-up router at any location of the network, because there is an underlying optical layer. Once a suitable path is found, ANM start the Automated IP Link Provisioning use case.

4. REQUIREMENTS

ANM enables the dynamic and automated control of server layer (EON) transport resources. However, based on Figure 1, ANM looks like a black box with multiple functionalities inside of it. ANM must have enough functionalities to cover use cases defined in previous sections. Figure 3 shows the functional blocks identified in the IDEALIST project. Each of the building blocks will be assessed during the project so a proof-of-concept will be done at the end of the project.

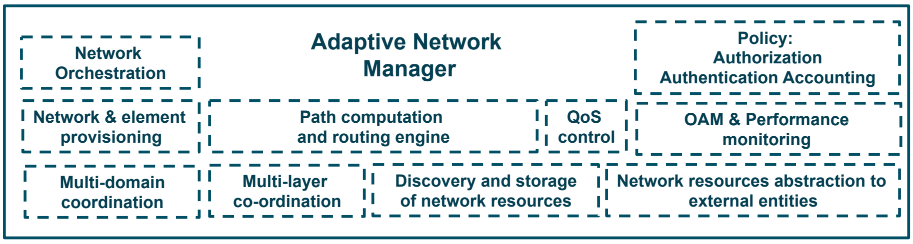

Figure 3: ANM functional building blocks

One of the key issues in ANM is the utilization of standard technologies, so ANM can operate in existing networks. From this perspective, there are three architectures related to concepts presented in the ANM: Active PCE [2], which is capable of set-up and tear down LSPs, SDN controller [3], which is defined mainly for OpenFlow controlled network elements and Application-Based Network Operations (ABNO) controller, recently proposed in IETF [4]. These architectures will be assessed when defining the functional blocks of ANM.

5. CONCLUSIONS

This paper presents the definition of Adaptive Network Manager (ANM), its use cases and the requirements in terms of functional blocks identified in the project. The Adaptive Network Manager (ANM) concept appears as a necessity for operators to dynamically configure their infrastructure based on user requirements and network conditions. Three architectures may fit with ANM requirements, but they will be evaluated as future work.

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