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Abstract

Future networks and services will be based on an all-IP design. If the IP layer and optical layers on a backbone network remain independent of each other, more powerful backbone routers will be required. Such routers will be more complicated and have higher power consumption, and higher costs. This will be a challenge for the carriers. The unified ASON control plane technology will help carriers in this challenge by synergizing the IP layer and optical layer, and providing unified grooming at the two layers. This technology will relieve the pressure on backbone routers, and reduce the costs for carrying these services, and it is an important part of Huawei SingleBackbone Solution. This document describes planning with IP&optical synergy in terms of key techniques, its strength and weakness; and also describes relevant technologies developed by Huawei, and an application example.

Key Words

IP, hierarchy, flat, OTN, network planning, heuristic algorithm

1 Overview

Future networks and services will be based on the all-IP technology. If the IP layer and optical layers on a backbone network remain independent of each other, increasing capacity on backbone routers will be required, leading to more complicated routers with more power consumption and higher costs. This will be a large challenge for carriers. The unified ASON control plane technology will help carriers overcome this challenge by means of IP&optical synergy, and provide unified grooming at the two layers. This technology will relieve capacity pressure on the backbone routers, and reduce the costs of carrying services. Proper planning of service routes; and allocating resources at the IP layer and optical layer will be an urgent issue. As an important part of SingleBackbone Solution, a multi-layer network planning technology which achieves IP&optical synergy is urgently needed. Many software companies and network equipment vendors attach high importance to research and development of multi-layer planning software and technologies, and have made a lot of progress in this area. One IP network software company has achieved smooth connection of network design between the IP layer and the optical layer by means of a data stream. Another software company considers a unified design tool as its product strategy, and has announced a plan to develop multi-layer design software.
2 Requirement Scenarios

Figure 2-1 shows data services grow with service transformation to packets and IP.

**Figure 2-1 Forecast of future service growth**

Bandwidth-eating services, like video services and IPTV services, require larger capacity on a network. As service charges decrease, ARPU declines. Operators expect service transport over a pipe with large granularities, but with low costs. The optical-layer equipment is up to the expectations; however, an operator cannot overcome the challenge of service growth based only on router devices or a single IP network.

When planning a network, an operator always separates the IP layer from other layers. The operator first plans the capacity of IP network according to the requirements of the traffic matrix at the IP layer, including the equipment at each node, and the interface bandwidth. The operator determines a solution of a transport network at the bottom layer according to the interface information at the IP layer. This approach divides a network into two stand-alone networks, which will result in the following problems:

- Sharp increase in network construction costs
- Complicated structure for future networks
- Route detour at the physical layer
- Failure to meet constraints for disjointed routes
- Resource waste
The following sections describe the above problems in details and provide solutions to them.

2.1 Sharp Increase in Network Construction CapEx

2.1.1 Problem Description

When a transport network and an IP network are built separately by using layer-by-layer network planning, all IP services have to be forwarded at intermediate routers, regardless of the granularities of them. This results in demands for increased capacity of the core routers as services grow at the access layer. A sharp increase in capacity of IP-layer equipment leads to demands for large capacity of the optical transport equipment at the bottom layer. This imposes a large challenge on CapEx reduction in network construction for operators.

2.1.2 Solution

The statistical multiplexing technology on an IP network is very different from the space-division transport technology on an OTN network. Routers consume more resources, and require higher CapEx compared with OTN devices for the same volume of traffic. As shown in Figure 2-2, large-granularity traffic streams between two nodes do not need to be forwarded on an IP network hop by hop any more. Instead, these traffic streams are transported over large-granularity pipes provided by an OTN. The IP network only needs to forward and converge a small volume of traffic, requiring less capacity on the routers. This not only relieves current pressure for the expansion and upgrade of the routers, but also reduces total transport costs for operators.

Figure 2-2 Solution to carrying service traffic
2.2 Complicated Structure for Future Networks

2.2.1 Problem Description

Currently, operators build their IP networks with a hierarchical structure where services are routed through layer-by-layer convergence. Though the hierarchical structure at the IP layer is critical to management and maintenance of the IP services; but operators will face the great pressure for network expansion, especially the core routers, as traffic increases quickly. In addition, nodes require a larger area in the telecommunication rooms and consume more power.

2.2.2 Solution

Though the technical advances are ongoing, commercialization of IP&optical synergy has a long way to go. Network structure convergence for IP network and optical network is a feasible solution currently. That is, a network structure evolves from "hierarchical" to "flat", as shown in Figure 2-3.

![Figure 2-3 Network structure evolution from "hierarchical" to "flat"](image)

The position of the traffic convergence point will change along with the network evolution, and traffic routes will become more and more complicated. Routing and traffic grooming at different nodes or layers will become more complicated. How do you reach a balance between service grooming and convergence? If the balance is based on manual operations, there will be critical issues about difficult and complex calculation, as networks and services grow. As a result, network design may fail. Multi-layer network planning can help resolve this problem.
2.3 Route Detour at the Physical Layer

This section describes the problem with route detour at the physical layer and provides a solution to this problem.

Figure 2-4 Route detour at the physical layer

2.3.1 Problem Description

Currently, the planning of the IP layer is always separate from the planning of the optical layer. Then, the planning hardly avoids route detour. Figure 2-4 shows a route detour. Assume that there is a T1 IP service from point A to point B. Three links at the wavelength layer are available for the service, marked in purple, blue, and green. The T1 on the east coast is routed across to the west coast during wavelength-layer routing. In this case, if T1 requires a certain delay, the delay requirement may fail to be satisfied as the optical layer cannot sense delay requirements of all services between two sites. As a result, user experience is affected.

2.3.2 Solution

When the service volume is low and network topology is simple, this problem is not urgent. The optical-layer trails of the IP service can be manually adjusted to resolve this problem. As the network and services grow, manual adjustment is not sufficient to resolve this problem. A network auto-planning tool can be used to calculate routes at the IP and optical layers based on service constraints, physical distance, and the number of router hops. The tool helps to avoid the route detour.
2.4 Failure to Meet Constraints for Disjointed Routes

This section describes the problem with a failure to meet constraints for disjointed routes and provides a solution to this problem.

Figure 2-5 Working trail and protection trail not separated at the physical layer

2.4.1 Problem Description

Currently, planning of the IP layer is always separate from planning of the optical layer. This may result in a failure of the planned trails at the IP layer to meet SRLG separation constraints during deployment at the physical layer. As shown in Figure 2-5, T1, an IP service starts from P1 and reaches P4. This service is under link FRR protection. If the P1-P6 link is a risky link, standalone planning of the IP layer may output an FRR protection trail of P1-P3-P6. During planning of the optical layer, the physical working and protection trails may both include the N1-N7 link. As a result, the working and protection trails may both fail in case of a fault of the N1-N7 link on the network.

2.4.2 Solution

As networks grow, the problem becomes more complicated and difficult to resolve, and manual adjustment is not sufficient. In this case, auto-calculation of the multi-layer planning tool can help resolve this problem. The multi-layer planning tool ensures not only disjointed routes at the IP layer, but also route constraints of the carrier physical trails on the physical topology.
2.5 Resource Waste

This section describes the problem with resource waste and provides a solution to this problem.

Figure 2-6 Resource waste

2.5.1 Problem Description

Currently, to provide protection for an IP service, an operator has to plan working and protection resources separately at the IP layer. To avoid overlapping of physical working and protection trails during the planning of the optical layer, the operator may not distinguish between the working and protection resources at the IP layer. Instead, the operator provides working and protection resources for the resources at the IP layer. As shown in Figure 2-6, four resources at the optical layer are planned to carry one resource at the IP layer. The resources are wasted.

Similarly, an operator wants to provide protection against two faults at the IP layer or optical layer. Currently, planning of protection resources at one layer is independent from that at the other. This results in resource waste.

2.5.2 Solution

The resources at the IP layer and optical layer must be jointly considered for service protection against \( n \) (\( n: 0 \) or \( 1 \)) faults to avoid a waste of resources at the optical layer.
3  Multi-Layer Planning Tool

According to the preceding analysis, a tool for unified planning of the optical layer and IP layer is required currently. The tool must consider the following:

- Various constraints of the optical layer and IP layer
- Resources available at the optical layer and IP layer
- Transport trails at the optical layer and IP layer

In addition, the tool must help optimize service trails to reduce network construction costs. The tool will achieve the IP&optical synergy to resolve the preceding problems.

3.1  System Structure

Figure 3-1 System structure

Figure 3-1 shows the system architecture of the multi-layer planning tool, which consists of the input module, the core planning module, and the output module. This section describes the three modules in detail.

3.1.1  Input Module

When starting network planning, a user needs to enter the service matrix information, the physical network topology information, the logical network...
topology information at the router layer (only for the hierarchical structure), the equipment model, the cost model, and various constraints. The details about the inputs are as follows:

- Service matrix information
  - Original source and sink nodes of services
  - Service bandwidth
  - Service protection type

- Physical network topology information
  - Nodes
  - Physical inter-node connections
  - Physical distance
  - Bandwidth

- Logical network topology at the router layer
  - Inter-node port connections
  - Bandwidth of inter-node port connections

- Equipment model
  The equipment model is based on physical routers and optical equipment, and covers various ports and cross-connect granularities specific to each layer supported by a node. Figure 3-2 shows the details. In Figure 3-2, the packet forwarding equipment is at the top layer which represents the IP layer; the ODUk layer is in the middle; the wavelength layer is below ODUk layer and wavelength-layer equipment includes the ROADM and MUX/DEMUX. When entering equipment model information, the user can select

Figure 3-2 Equipment model
input/output ports, and specify the OTN-layer service mapping modes on nodes at each layer. The various equipment groups can be emulated.

- Constraints
  - Constraints for disjointed routes (SRLG, link, and node)
  - Constraints on included and/or excluded nodes and/or links
  - Link utilization
  - BCM properties

3.1.2 Core Planning Module

The core planning module selects proper grooming layers and proper nodes at different grooming layers for services according to the optimization objectives specified by a user, including optimal network construction costs; and load balance at the wavelength layer or router layer. This module optimizes the planning based on the iterations between the different grooming layers to try to achieve the optimal objectives for the network.

3.1.3 Output Module

This module outputs service route information, node configuration information, network construction cost information, and wavelength allocation information. The details about the information are as follows:

- Service route information: service carrier channels and routes along each channel at the physical layer
- Node configuration information: various ports required at each node, such as GE/10GE equipment at the router layer, and ODU1, ODU2, OADM, OA, and MUX/DEMUX at the optical transport layer
- Network construction cost information: cost information about each node and equipment at each layer
- Wavelength allocation information: wavelengths allocated for each channel

3.2 Calculation Process

Figure 3-3 Calculation process
Figure 3-3 shows the process for planning the multiple layers (TE + optical). The planning of each module is as follows:

- **System input**: Enter planning information. Abstract the equipment model to minimize its association with the following core planning modules.
- **Service route**: The tool calculates service routes at each network layer according to certain constraints and optimization objectives for network planning. Constraints at the optical layer and IP layer may specify SRLG/link separation, and excluded or included nodes or links.
- **Iteration of optimization**: Based on certain rules, such as the random rule, the tool runs iteration on service routes at the IP layer and optical layer by using a heuristic algorithm. Then the tool gradually produces a near-optimal solution.
- **System output**: The tool outputs service routes (including carrier channels and configuration of equipment at each node along a channel), and various statistical information (including costs and utilization).

### 3.3 Core Values of the Tool

The multi-layer planning tool helps an operator resolve the preceding problems based on the existing physical topology, and traffic model of a live network. In addition, the tool provides information about future network construction, including costs, service routes, and equipment configuration. It provides optimal network construction guidelines by comparing different solutions for building future networks. The functions of the multi-layer planning tool and its output information are listed as follows:

- **Minimizes network construction costs regardless of whether the network is a hierarchical or flat structure**. The tool creates planning results about how IP services can be routed at the IP layer and optical transport layer, and how to configure equipment at each node, to achieve minimum costs per bit.
- **Determines whether a 40G port rate will satisfy the requirements for a future network based on the current traffic model; and, if not, when expansion to a 100G port rate should be executed.**
- **Predicts the requirements about the capacity of core routers, telecommunication rooms size, and power supply N (N ≥ 1) years later based on the current network hierarchy.**
- **Determines whether to provide GE/10G ports, GE/2.5G/10G ports, or 10G ports between routers and optical equipment N (N ≥ 1) years later.**
- **To different services, judges what protection (at the IP layer or ODUk protection at the optical layer) will reduce network construction costs.**
- **Determines whether pressure about capacity expansion of the core routers can be relieved on a flattened network; and compares a flattened network and a hierarchical network with respect to CapEx and OpEx N (N ≥ 1) years later.**
4 Application Scenarios

4.1 Application Example

An example of future network planning for a European operator based on the TE & optical planning technology is shown. A comparison is made between the traditional hierarchical network and multi-layer network based on multi-layer planning according to the service matrix information and network topology information provided by the operator. As services grow by 60% every year, CapEx and OpEx per year specific to each network can be predicted as shown in Figure 4-1.

Figure 4-1 Comparison in aspects of costs, area of equipment rooms, and power consumption
• If services grow by 60% per year, the traffic will be 6.5 times the current traffic in five years. A multi-layer network may reduce network construction costs by 30%, reduce the router equipment room area by 50%, and reduce power consumption of the routers by 55%, compared to a hierarchical network.

The TE & optical multi-layer network planning tool can help operators understand clearly how to design their networks for the future.

If you need more information about SingleBackbone Solution
http://www.huawei.com/broadband/iptime_backbone_solution.do