A Systematic Approach to Develop and Manage SRLGs for Optical Transport Networks with Multi-Tier Resources

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Abstract: This paper presents a generalized framework that characterizes multi-tier resource dependency and operators' diversity policies in transport networks. The framework enables the design of systematic approaches toward SRLG development for optical transport networks.
OCIS codes:(000.4930) General, (000.2170) General

1. Introduction

The transport network industry has adopted Shared Risk Group Identifier (SRG_ID) as a means to indicate shared risks among network resources. A SRG_ID is an integer representation of a specific risk shared by a set of network resources. A formal definition and format of SRG_ID is given in [1,2]. For public carrier networks, SRG_ID development is a huge effort due to the sheer volume of network resources to consider and the multi-tier nature of risk sharing behavior among these resources.

This paper presents a systematic method to develop and manage SRG_IDs for public optical transport networks (OTN) with multi-tier resources. Merits of the proposed method are (1) it establishes a general framework to manage multi-tier SRG_ID development for multi-layer networks, (2) it provides network operators an algorithm-based procedure to develop SRG_IDs and shared risk link group (SRLG) for OTNs, and (3) it lays a foundation on which a fully automated SRG_ID generation and management system can be developed.

2. A Generalized Shared Risk Group (SRG) Framework

This section describes a generalized SRG framework to support a systematic approach to SRG_ID development for OTNs. The SRG framework characterizes multi-tier resource dependency of control plane (CP) managed resources and reflects operators' diversity policies. The framework consists of following components: resource groups, diversity or risk-sharing policy, and rules to assign SRG_IDs.

Resource Groups: Network resources involved in path diversity requirements can be partitioned into groups according to their physical sharing relationship. For instance, an operator may impose following requirements for working and protection (W&P) paths of 1+1 protected circuits: (1) W&P paths are fully diverse with respect to fiber cables, (2) Fiber cables on W&P paths don't share any manhole, and (3) W&R paths don't originate or terminate on same circuit pack. For the example, two resource groups can be generated; these are fiber-cable and circuit-pack groups. In the fiber-cable group, there are fiber-cable and manhole, modeled as a two-tier hierarchy with fiber-cable on Tier 1. The circuit-pack group contains circuit-pack resources at Tier 1. A graphic representation of the two-tier (fiber cable & manhole) resource group is shown in Figure 1.

The following rules govern the construction of multi-tier resource groups:
a. All resources considered in diversity requirements should be partitioned into one or more resource groups, depending on network operators' path diversity policies;
b. The association between lower tier resources and its next upper tier resources can be either none, one-to-one, one-to-many or many-to-one depending on actual inter-tier physical relationship.

Diversity Policy: A network operator can impose additional diversity policies on various resource types. As an example, an operator can make it a policy that manholes that lie within 20 feet from each other are considered sharing the same risk. Such policies generate a need to introduce policy-based shared risk identifiers in addition to the regular resource-based shared risks like fiber cables. Network operators can implement one or more policies for each resource type. In Figure 1, two policies are shown, one for each tier.

Assignment Rules for SRG ID: Both resource-based and policy-based SRG_IDs have to be assigned from

the same identifier space (32-bit space). An application of the rule is shown in Figure 1, where each physical resource in the resource group is assigned a resource-based SRG_ID as represented by an integer (mn).

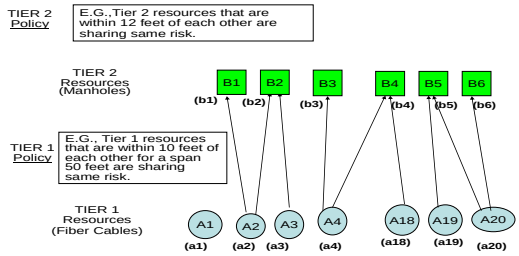

Figure 1 – An Example of a Two-tier Resource Group

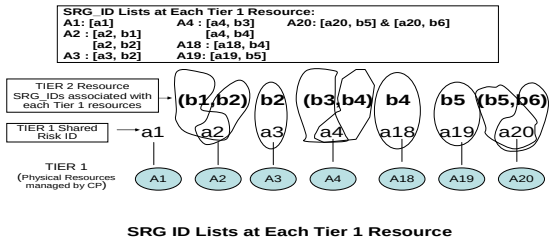

Figure 2 – SRG_ID lists for Figure 1 example

3. SRG_ID Development Method

With the SRG framework fully specified, the method described herein can then be applied to each resource group to create a multi-tier shared risk ID (SRID) tree for the group. Each SRID tree consists of two parts: resource-based and policy-based sub-trees. The procedure to create these sub-trees is summarized below.

Resource-based Sub-tree

Step 1. For each Tier 1 resource in a resource group, list out its Tier 1 SRG_ID along with the SRG_IDs of all upper-tier SRG_IDs that the resource has a direct or indirect containment relationship. Figure 2 shows graphically the SRG_ID list for each Ax resource of the resource group in Figure 1.

Step 2. Scan the SRG_ID lists generated in Step 1 for Tier 2 and above, and select the SRG_IDs on each tier that support multiple Tier 1 resources directly or indirectly. List out the selected SRG_IDs on the level corresponding to the tier. Each selected SRG_ID is the root of an up-side-down tree with two or more branches connected to Tier 1 resources that share the SRG_ID. Repeat above procedure for all Tiers. Figure 3 depicts the results of applying above procedure to the SRG_ID lists in Figure 2.

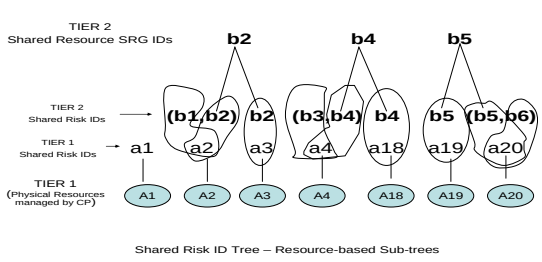

Figure 3 – Resource-based sub-trees for the example

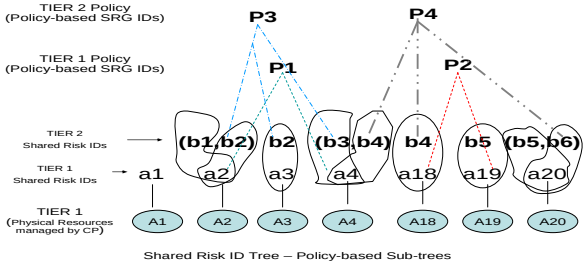

Figure 4 – Policy-based sub-trees for the example

Policy-based Sub-tree

Step 3. Derive Tier M policy-based SRG_IDs by applying a Tier M policy on Tier M resources and marking each pair of the resources that violates the policy. Identify all closed SRG groups (CSG) from the pair-wise markings. A CSG is any subset of Tier M resources in which every possible pair are involved in at least one policy violation instance. Each CSG will be assigned a new policy-based SRG_ID (P-SRID) to represent the shared risk of all resources in the CSG. Each Tier M P-SRID is the root of a sub-tree with multiple branches to Tier 1 resources that violate the policy. For the Figure 1 example, the procedure generates four policy-based SRG_ID sub-trees with roots at P-SRIDs P1 and P2 on Tier 1 and P3 and P4 on Tier 2, as shown in Figure 4.

Complete Multi-tier SRID Tree

Step 4. Form a complete multi-tier SRID tree by super-imposing all SRG_IDs developed in Steps 2 and 3 for each tier. For each Resource-based or Policy-based SRG_ID (SP-SRG_ID), determine its sharing scope that is defined as the set of Tier 1 resources sharing the SP-SRG_ID. In Figures 3 and 4, the sharing scope of each SP-

SRG_ID can be represented graphically by the tips (i.e., Tier 1 resources) of its sub-tree branches. All SRG_ID trees can be super-imposed to form a multi-tier arrangement as illustrated in Figure 5. There are three types of SRG_ID trees: (a) Root only tree, like the tree at "a1" for resource A1 in Figure 5, (b) Single branch tree, like the tree at Tier 2 "b1" with single branch to "a2" at resource A2, and (c) Multi-branch tree, like the trees rooted at "b2" and "P2". Apply following rules to develop the final SRG_ID assignments for each Tier 1 resource, which will then be used by the optical control plane to support end-to-end path diversity.

Rule (a): Only roots of SRG_ID trees can be candidates for final SRG_ID assignments for Tier 1 resources;

Rule (b): For each Tier 1 resource, any unshared, highest-tier SRG_ID (i.e., roots of root-only or single-branch trees) must be included in the final SRG_ID assignment for the resource; In Figure 5, SRG_IDs "a1" and "b1" are unshared SRG_IDs to be included as part of final SRG_IDs for Tier 1 resources A1 and A2, respectively.

Rule (c): For each Tier 1 resource, identify all SRG_IDs (resource- or policy-based) that are shared by more than one Tier 1 resources and are at the root of a multi-branch SRID tree. The shared SRG_IDs so identified are filtered by their sharing scopes. If a shared SRG_ID's sharing scope is fully contained in the scope of another shared SRG_ID, the former will be disqualified.

Rule (d): The final SRG_IDs assigned to each Tier 1 resource will consist of root SRG_IDs of following SRG ID trees that touch on the Tier 1 resource: root-only trees, single-branch trees and remaining multi-branch trees. For the Figure 1 example, the final SRG_IDs for each Tier 1 resource is summarized in Figure 5.

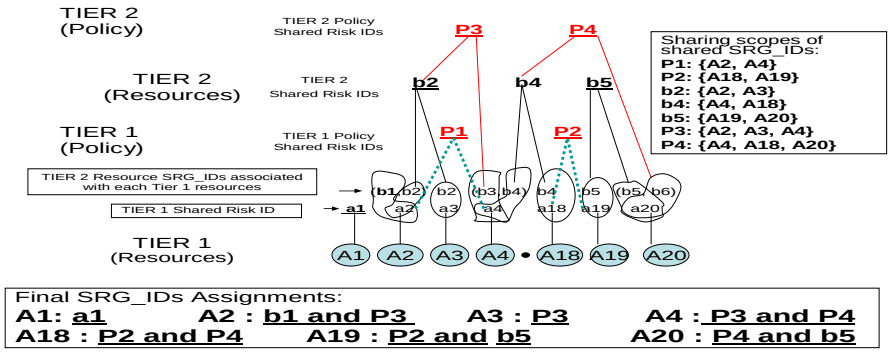

Figure 5 – Complete multi-tier SRID tree and final SRG_ID assignments

At the end of above procedure, every Tier 1 resource in each resource group will have a set of final SRG IDs assigned, which can then be used to create SRLGs for control plane links.

4. SRLG Assignments on Control Plane Links

SRLG is a CP link attribute monitored by CP routing process to perform disjoint paths calculations. For each CP link, its SRLG is the union of the final SRG_IDs of all Tier 1 resources used by the CP link. The SRLGs for all CP links must then be configured on the CP to ensure end-to-end path diversity. However, there are situations when (1) network resources have to be rearranged to meet network performance requirements or (2) the SRLG on a CP link contains more SRG_IDs than platforms can handle. In such cases, separate approaches like SRG_ID aggregation is needed, which is outside the scope of this paper.

5. Summary

This paper describes a system to design and manage multi-tier risk-sharing network resources to support circuit diversity in optical transport networks. The system lays a foundation on which a fully automated SRG_ID generation and management system can be developed. The approach enables service providers to implement SRG_ID assignment systems for CP-capable OTNs, and has been extended for application to multi-layer networks, where SRLGs used by Layers 2 and 3 platforms can be derived from SRLGs on the OTN layer.

6. References

[1] IETF RFC4203, K. Kompella, Y. Rekhter, Ed. "OSPF Extensions in Support of Generalized Multi-Protocol Label Switching (GMPLS)".

[2] IETF RFC4258, D. Brungard, Ed. "Requirements for Generalized Multi-Protocol Label Switching (GMPLS) Routing for the Automatically Switched Optical Network (ASON)".