Evaluation of Recovery Methods for Layer-1 Bandwidth on Demand Service

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Abstract This paper proposes and evaluates recovery methods for high-availability layer-1 BoD service. It also proposes a segment recovery architecture that hides the recovery operation from the users' view. Evaluations in an experimental environment are reported.

Introduction

The dynamic resource allocation network called layer-1 Bandwidth on Demand (BoD) service network is needed to cope with the start of digital broadcasting and the widespread use of large capacity network applications. The layer-1 BoD service network provides fixed bandwidth end-to-end paths for users during specific reserved times. For mission critical applications, this network needs to provide high availability paths. This paper proposes and evaluates recovery methods for a high availability layer-1 BoD service. This paper also describes a segment recovery architecture that uses virtual switching interfaces to hide the recovery operation in the network from the users' view.

Bandwidth on demand service characteristics

The BoD service dynamically allocates layer-1 bandwidth resources in response to user requests. We have already proposed a layer-1 BoD service architecture, composed of a layer-1 BoD server and layer-1 nodes [1], and started its basic service for research projects in the real network, called SINET3, in 2008. The layer-1 BoD server has admission control, traffic engineering for path route calculation, path control, and resource management functions. The layer-1 switches establish layer-1 paths by using GMPLS (Generalized Multi-Protocol Label Switching) signalling [2]. Key path parameters of user requests include endpoints, the bandwidth, and start and end times. For mission critical applications, we are planning to allow users to use high availability paths. In this case, as an option for path properties, users can select path recovery types, which are non-protection, link/end-to-end protection, or restoration. The subtle distinction between protection and restoration is made based on the resource allocation approach used during the recovery phase. The protection mechanism fully establishes a protection path before failure occurs. The restoration mechanism establishes the restoration path only after failure of the working path.

Proposed Recovery methods

We propose two types of recovery methods based on restoration. Method 1 uses pre-computed recovery routes; method 2 calculates the recovery route after detecting a failure.

Method 1 (pre-computed):

Figure 1 shows our method 1. Layer-1 BoD server calculates working and recovery path routes at the same time when a user request arrives. At the starting time of the path, layer-1 BoD server requests path establishment to the ingress layer-1 node. At this time, the ingress layer-1 node establishes the working path, not the recovery path. It keeps the recovery path route. If a failure occurs, the recovery path is established via the pre-computed route. If the failure affects the recovery path route, the ingress node requests another recovery route from the layer-1 BoD server.

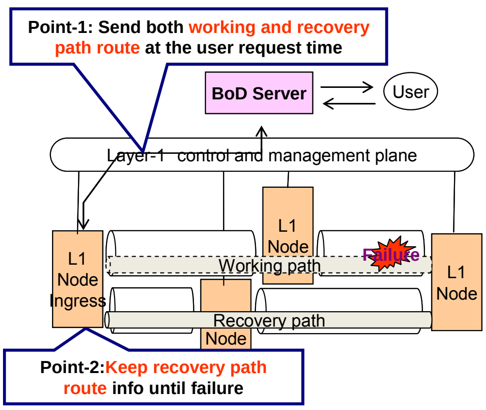

Fig. 1: Recovery method 1

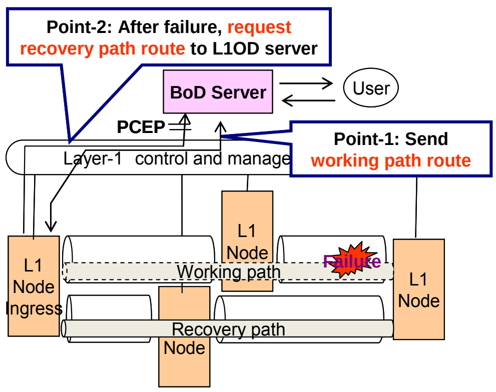

Fig. 2: Recovery method 2

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Method 2 (compute after failure):

Figure 2 shows our method 2. Layer-1 BoD server calculates just the working path route when a user request arrives. When a failure occurs, the ingress layer-1 node requests a recovery path route to the layer-1 BoD server by using PCEP [3]. The layer-1 BoD server selects the available network resource (which excludes failed resources) at that time. Next, the layer-1 BoD server replies to the ingress layer-1 node with the recovery path route; the layer-1 node establishes the recovery path by using GMPLS signalling and switches the traffic data from the working path to the recovery path.

Comparison of our methods

Table 1 compares our two methods from three aspects. Method 2 thas longer recovery time (T_R) than method 1 due to recovery route acquisition time (T_G). Methods 1 and 2 have basically the same failure detecting time (T_D), recovery path establishment time (T_E), and switchover time (T_S). However, T_G may not take much time compared to T_E if layer-1 nodes take a long time to establish paths. From the viewpoint of recovery success rate and resource utilization efficiency, method 1 offers only low rates because the pre-computed recovery route may be damaged by the failure and so not available for recovery. It is assumed that the recovery resource is available in the network when the failure occurs. If the recovery resource is not assured of being available, the success rate and the resource efficiency of method 2 are not 100%. They are $R_{S1} \leq R_{S2}$ and $R_{E1} \leq R_{E2}$.

Proposed segment recovery architecture

We propose a segment recovery architecture that hides the recovery operation in the network from the users' view (Fig. 3). The established working path, which has a recovery route, is handled as a segment link. End points of the segment link are identified as virtual interfaces. The segment link accommodates users' end-to-end layer-1 paths via two virtual interfaces. Even if a failure occurs in the working path and the segment link is switched from the working path to the recovery path, the virtual interfaces are not changed and the user layer-1 path routes are not changed.

Tab. 1: Comparison of recovery methods

	Method 1	Method 2
Recovery time	$T_R = T_D+T_E+T_S$	$T_R = T_D+T_G+T_E+T_S$
Success rate	$R_S \leq 100\%$	$R_S = 100\%$
Resource efficiency	$R_E \leq 100\%$	$R_E = 100\%$

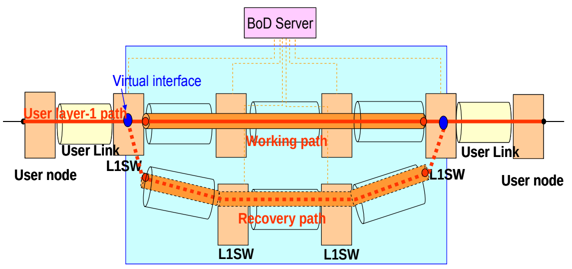

Fig. 3: Segment recovery architecture

Evaluation and Implementation

We evaluated the proposed method in a laboratory experimental network consisting of two edge layer-1 switches and four core layer-1 switches (Fig. 4). We confirmed that a working path was established between core layer-1 switches and was handled as a segment link. A user layer-1 path was established between edge nodes via the established segment link. When we caused a failure on the working path by detaching the optical fiber, the end point node (core node 3) of the segment link established a recovery path via core nodes 1 and 2 and switched traffic data to the recovery path from the working path. In our evaluation environment, the switchover time was 18 seconds and the recovery path establishment time was 17.8 seconds. In this case, the VC-4-Nv recovery path was established by one VC4 signal. Therefore the recovery time was independent of N and almost the same.

Conclusions

This paper described recovery methods for the layer-1 BoD service network and a segment recovery architecture that hides recovery operation during switchover from the user. An evaluation using a laboratory experimental network confirmed the operation of our proposed recovery methods. We are planning to introduce these methods into SINET3 in the very near future.

References

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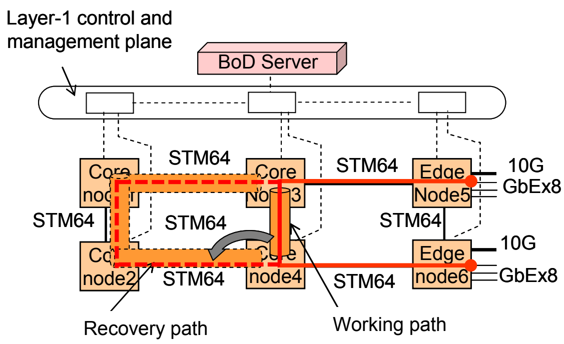

Fig. 4: Experimental network and test results