A priority-based IP/MPLS management scheme Case-study: Smart Grids

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Paper Reference Number: 6-02-25-2012
Presenter: Bahareh Mobasheri

Abstract

To provide dependable services, IP/MPLS networks make use of a set of procedures (detection, notification and fault recovery) which is used to ensure appropriate protection for the traffic carried in the LSPs. One of the basic recovery models used to redirect traffic is the protection switching. In this paper we focus on the fault recovery issue in protection switching and use a priority-based scheme to overcome the link/node failures that may happen in an active LSP. By considering an IP/MPLS network as an infrastructure in a Smart Grid, and giving priority levels to all the incoming requests from the grid, we show that resources are used more efficiently and an adequate QoS can be achieved.

Key words: failure recovery management, traffic demands, priority level, smart grid, IP/MPLS;

1. Introduction

The aim of this paper is to introduce a recovery mechanism in an IP/MPLS(Internet Protocol/Multi Protocol Label Switching) network. We use a Smart Grid as a case-study and apply the IP/MPLS network as an infrastructure in the Grid. A priority level is considered for each of the traffic demands, being sent from a Smart Grid, entering an IP/MPLS domain. High priority (HP) traffic can preempt low priority traffic. We assume that the high priority(HP) Label Switched Paths (LSPs) as long-lived LSPs, e.g. they are used for VPNs, and thus their configuration is not changed often. Therefore they can carry a significant amount of traffic. Bandwidth reserved for backup LSPs of HP demands, in normal conditions, can be used by low priority LSPs. Since the high priority LSPs require to be long-lived LSPs and have 100% survivability, it is important how the network resources are used for their protection because this implies how many low priority LSPs are discarded from the network when backup paths for HP demands are activated.

In a network, the demands are divided into two categories: high priority demands and low priority demands. It is assumed that only the high priority demands need to have 100% survivability and other demands can be recovered only if resources are available, in the order of priority.

Based on this differentiation of the demands, a network protection method is proposed. In this method a failure-dependent backup path(FDBP) protection mechanism with sharing of backup capacity is used for assuring availability of the HP demands. A failure-dependent backup path is a list of possible failure scenarios affecting the active path, and the backup paths depending on particular failures are pre-determined. In general, FDBPs allow for a more effective way of using the network resources than using single(failure-independent) backup paths(SBPs) in all failure situations. When a failure occurs, based on the failure, the specified backup paths matching the failure are activated and used to carry the flows until the active paths are repaired. As soon as the active path is recovered, the traffic will be switched back to it.

The protecting mechanism used in this paper is restricted reconfiguration mechanism. In restricted reconfiguration only the faulty links that relay on the active path, transmit to the backup path and the rest of links remain unchanged.

In the proposed method, in order to manage the failures in IP/MPLS networks the active and backup paths should be failure-disjoint, i.e. the active and backup paths do not share the faulty element. The non-failing resources of a given active path can be reused by a backup path of a demand. And also the unused resources of the backup paths can be used by other demands. Considering different priority levels for all the traffic demands coming from the Smart Grid is essential.

A Smart Grid is complex system of systems and sub-networks. In this work we use IP/MPLS network to consolidate these disparate sub-networks and introduce a recovery mechanism using a priority-based technique, to overcome the failures occurring in the network[3].

The rest of the paper is organized as follows: First an overview of a Smart Grid and a brief explanation of its' utilities' sub-networks is given. In section3 the proposed recovery mechanism is introduced and explained in details. The proposed mechanism is applied in a Smart Grid and will be discussed in more detail in section4. The paper ends up with a conclusion.

2. Basic Smart Grid System

Generally, Smart Grid is a data communication network integration with the electrical grid that collects and analyzes data captured in near-real-time about power transmission, distribution, and consumption[2]. Based on these data, Smart Grid technology then provides predictive information and recommendation to utilities, their suppliers, and their customers on how best to manage power. Within utilities there are several types of networks deployed: AMI, VOICE, VIDEO, SCADA, Corporate, etc. Also Datacenters are used to enable the networks to communicate with each other and get the required information. Each one of these networks is maintained and supported independently. Therefore the demands coming from these sub-networks do have different level of importance and thus different priority levels. A brief explanation of some of these networks is given:

Advanced Metering Infrastructure (AMI) network:

An AMI network is designed to help customers know the real-time prices of power and optimize power usage accordingly. Also, consumers become informed participants, and they can choose different purchasing patterns based on their needs and the Grids' demand, which can ensure the reliability of the electric power system.

In AMI and VOICE networks within a utility, time delay and availability becomes critical.

Supervisory Control and Data Acquisition (SCADA) network:

SCADA network is one of the main components of the Electric Management System(EMS) which in cooperation with security application softwares and applying the right devices, assures the security with the use of Bulk electric power grid control. In SCADA networks, network availability becomes very important.

3. The proposed IP/MPLS failure recovery mechanism

The main focus in this study is to extend, enhance and combine the investigations of the recovery mechanism presented in [1][2][4] and at the same time applying the proposed method in a Smart Grid.

In [1] the long-lived LSPs are considered for all the active paths but in this paper only the defined higher priority traffics will be passed through such LSPs.

Throughout this paper when discussing the failure occurances in an active path, we mean the “link failures” and the proposing mechanism can also be easily applied for node failures.

Consider demands are sent from an outside network in the form of IP packets. After entering the IP/MPLS domain, IP packets receive their associated labels at ingress LSR. Then pass their way through the network. In this paper we propose to consider a new field on the packet label and name it **priority** field. Outside networks will be given priority levels. By initializing the priority field of each packet at the ingress LSR the importance of the passing traffic can be determined. In the case of any network element failure the failure must have the minimum affect on the demands that are received from high priority(HP) networks and their traffic must be passed through the backup LSP with maximum speed and minimum delay. Therefore using the

protection switching model seems adequate. As we know already, in the protection switching model both the active and backup paths are pre-signaled in the beginning and the required bandwidth is reserved for them. The waste of resources is obvious in this model. The newly proposed method will recover this disadvantage by allocating the backup bandwidth to the lower priority demands, in the normal state.
For the proposed method to work properly some requirements are needed to be provided by the network.

System Requirements

1. A list of the networks and the systems that are to be in contacts with each other via the IP/MPLS infrastructure and defining priority levels for the incoming traffic demand from each of them.
2. A list of long-lived LSPs for the high priority traffic demands.
3. Provisioning a list of scenarios which can happen for each of the long-lived LSPs. All the scenarios related to each LSP should be reachable by all the PSLs located in that LSP.

All the three mentioned issues need to be available in the ingress LSR.

Consider a traffic, sent by a HP network, entering an IP/MPLS domain. In the ingress LSR, the source of the traffic packets are read. Due to the source, the priority fields receive their associated value (in this case the highest priority level). Therefore a long-lived LSP is used to carry the incoming packets through the network. The list of scenarios of possible failures for this specific LSP is already known. The traffic continues its' way toward the egress LSR. As soon as the first packet of this traffic is seen by the egress LSR, a Received Indication Signal(RIS) is sent to the ingress LSR. This signal shows that this traffic has had its' first pass through this active LSP, and seems that the LSP has no problem. One the other side when receiving this signal, the ingress LSR discards it (this happens only if before receiving the RIS, a FIS is not received by the ingress LSR) and the backup bandwidth will be used by the lower priority demands. And therefore the lower priority demands get accepted and are not ignored by the network. As can be seen, the mechanism used is the global mechanism.

Now consider a case in which a report of a failure, in an active path, is received by the upstream LSR. By applying the local mechanism, the nearest PSL in the path refers to the list of pre-determined scenarios and chooses the right backup path. This backup path (a Detour path)starts from the nearest LSR before the faulty link(upstream LSR) and ends in the LSR just after the faulty link(downstream LSR). Then by doing the necessary changes in the routing table the traffic switches to the backup path. At the same time, the LSR detecting the failure, sends a FIS to the ingress LSR. With the FIS, the upstream LSR reads the capacity of the backup bandwidth used by the backup path from the routing table and sends it to the ingress LSR. After receiving this information the ingress LSR subtracts the backup bandwidth used from the residual backup bandwidth. In case a RIS is received, the available bandwidth is divided among the lower priority demands. In this method, to avoid using wasting resources, only the long-lived LSPs will have detour paths as backup paths and the rest of LSPs act as they do in a normal protection switching models.
It is obvious that by using this method the backup path uses a lower bandwidth in compare to the method proposed in [4]. In [4] the backup path starts from the upstream LSR and ends in the egress LSR, thus in that way more bandwidth is needed to overcome the failures.
In the method proposed in this paper the active and backup LSPs are failure-disjoint and the restricted configuration is applied. Consequently the resources are used more efficiently. It is clear that the mechanism used in this method is a compound of both the global and local recovery.

4. Applying the proposed method in the Smart Grid

Consider an IP packet arriving from one of the networks of an utility(AMI, VOICE, SCADA, Corporate, ect) . When entering the IP/MPLS domain, the ingress LSR reads the value of the source field from the label of the packet. According to the table shown below, which is reachable by ingress LSR, the priority level of the arrived packets, based on the source field, and hence the traffic on the way can be determined and the priority field is initialized.

Some of the available sub-networks in utilities of a Smart Grid and their priority levels are shown in table1.

Network/sub-system	Priority level
AMI	0
VOICE, VIDEO	1
SCADA	2
Corporate	3

Table1: Priority levels for a Smart Grid arriving requests

As can be seen there are various traffic demands in different networks in an utility in a Smart grid and they are expected to be treated differently in passing through an IP/MPLS network.

As can be seen from the above table, the value of priority fields of packets (or demands) coming from AMI networks are defined to have the highest value, i.e. “priority=0”. As explained earlier the AMI networks are required to be necessarily near real-time networks. Thus the requests sent or received by such networks should be responded in near real-time. The availability of such networks must be high and their time delay should be as low as possible. By defining the AMI network requests as having the highest priority in the list, LSPs with 100% survivability will be considered for them. In the case of a failure occurance in an active path the recovery mechanism introduced in the last section will be applied. And when the active path is working properly the lower priority level requests get responded and do not get ignored by the network.

The priority fields of packets sent from the VOICE and VIDEO networks will have the value of “1” and so on.

> *Note:* It is completely optional how to define the priority levels of the traffic demands. We can have more than one traffic demand type having the highest priority level. Once it’s defined, it should be applied for all the traffic demands accordingly. For instance the traffic demands arriving from the VOICE and VIDEO can also have the priority value ‘0’ and so on. But it should be kept in mind that the number of long-lived LSPs are fixed and known and we should avoid causing congestion by defining a lot of traffic demand types having the highest priority.

Finally, Corporate networks and Datacenters will have the next priority values respectively. As they are responsible for providing the required information needed by other networks and therefore connecting to them need not to be real-time.

5. Conclusion

The paper considers an enhancing a traffic recovery mechanism in an IP/MPLS network carrying traffic with different priority levels. Then a Smart Grid is considered as a case-study, having the IP/MPLS network as an infrastructure, to apply the proposed mechanism. Investigations show that by giving priority levels to the incoming requests from the utilities in a Smart Grid an adequate QoS is achieved. By applying the proposed method it is shown that when failure occurs in an active path the proposed recovery mechanism, using a new introduced RIS signal, is activated and the resources are used more efficiently.

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