DETOUR PATH RESOURCE MANAGEMENT METHODS FOR IP SERVICE OPERATION

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Abstract: In the conventional IP network, equipment has been managed by periodical SNMP polling and periodical ping by a network management system (NMS), and traps have been used when abnormalities occur. But it is difficult to operate a service related to network state changes by such a management method because IP network services are best-effort services, so they may be affected by other multiplexed traffic. In order to solve such problems, we propose a detour path resource management method for IP networks. We discuss its advantages and how to overcome problems and verify that IP network resource management that includes detour path management is sufficient for practical use.

1 INTRODUCTION

To offer QoS-guaranteed video streaming services in an IP network, it is effective to use a Bandwidth Broker (Masuda et al., 2002) that controls a user's access according to the network resource situation. The Bandwidth Broker specifies the network topology and service paths by using a network Resource Management Server (RMS) that can comprehend the bandwidth of the network. But, this is not sufficient. A service cannot be called a QoS-guaranteed service unless the service traffic paths that bypass the failure point are immediately specified after abnormalities. The RMS needs to specify detour paths at the time of failure and inform the Bandwidth Broker which resources need to be managed.

In an IP network, there are various real-time path management approaches based on a server such as an RMS. However, there are discrepancies between the service path information stored by the server and the real network situation, whichever method is used, because of the processing delay of the RMS required for refreshing path information and re-calculating shortest paths (SPs).

On the other hand, an RMS can specify service paths using weight (cost) information of OSPF (Moy, 1998) or IS-IS (Callon, 1990). And the Bandwidth Broker can store detour path resource information that the RMS specified. In this method, the Bandwidth Broker can reallocate management resources to detour paths at the moment of failure detection. However, it is not realistic to store all (detour and shortest) path information in a database, because obtaining all detour paths makes the number of assumed fault patterns huge depending on the network scale. So, we propose a "Look-ahead type" detour path specification method.

We succeeded in reducing the number of calculations required for detour paths by using an RMS that implements the "Look-ahead type" detour path specification method. First, this paper describes the Bandwidth Broker type QoS-guaranteed service which is the target. Next, we describe related work, especially topology management approaches that have been proposed. Then, we explain our "Look-ahead type" detour path specification method. In section V, we evaluate the usefulness and implementability of our method by testing an RMS that implemented our method. Conclusions are drawn in section VI.

2 QOS-GUARANTEED SERVICE

In this section, we describe Bandwidth Broker type QoS-guaranteed services using an RMS. One of the biggest causes of poor video streaming quality is congestion caused by multiplexing. If packet loss occurs because of the congestion, the time sequence of the

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video information will be spoiled and the pictures will deteriorate. In video streaming, the user is looking at the screen for a long time. That is, video streaming is a service in which quality deteriorates in a conspicuous manner. Moreover, the system must react to the user's demand in real time. So we have been investigating how to achieve QoS-guaranteed video streaming services using the Bandwidth Broker model (Masuda et al., 2002) (Zhang et al., 2000).

For example, we have proposed a service whose quality is guaranteed for live distribution and video meetings where the time of use is fixed beforehand (Figure 1).

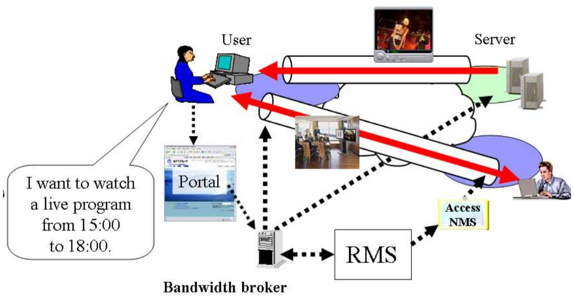

Figure 1: Quality reservation service.

First, the user tells the RMS when the service is required. The system checks free resources of the shortest path at that time, and reserves quality. As a result, the service can guarantee the quality of a target time slot by performing priority control at the appropriate time. Since the service can acquire time information from the user beforehand, a Bandwidth Broker can judge in advance in which time slot the service operator should guarantee the quality of which service. For a user, if reservation is approved, a guarantee of quality can be received certainly, and if it is not given, it may be possible to re-schedule in advance.

In contrast, if a distribution demand comes immediately from a user like a video on demand (VoD) service, the type of reservation described above is not applicable (Figure 2).

For such a service, it is effective to provide a guarantee of quality based on an understanding of the consumption of each resource in real time and access control judgment according to the network resource situation.

In these services, a RMS needs to process a user's access in real time. Therefore, the burden on a system is large and resource calculation cannot be done before the deadline in a large-scale network. For load balance, it will be necessary for the RMS which prepares path and resource information to be separated

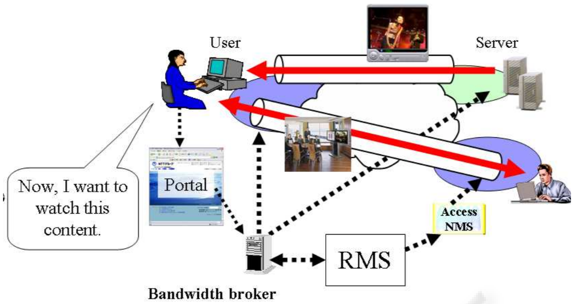

Figure 2: Real-time access control service.

from a Bandwidth Broker which receives a user's access. Even in a conventional IP network, a Bandwidth Broker can provide video contents to a user with quality ensured by comprehending the resource situation and controlling access to content.

Next, we describe the network resource information of the RMS required for access control by a Bandwidth Broker. What network resources should be managed in order to ensure such service quality? On an IP network, the typical resources that a service consumes are related to the switching performance of a node (a router or switch) and the bandwidth (interface speed) of a network link. If a network is designed in advance by operator as its switching performance is greater than bandwidth, then our RMS should provide bandwidth capacities as the network resources with service path information to a Bandwidth Broker. However, what is necessary is not just to treat wire speed (the IF speed that enables MIB-II to acquire data by SNMP) as a resource in that the service quality is managed. It is necessary to take into consideration the quantity of control protocol traffic and the burstiness of service traffic.

Next, we describe methods for selecting service paths. To manage bandwidth capacities of service paths, the RMS has to specify each link from edge routers that connect to the server to the edge routers that connect to user nodes. If the service is an interactive one such as a videophone, then the RMS has to specify the path from an edge router connected to a caller to an edge router connected to the destination user. For this reason, an RMS specifies the paths between any two points. In particular, it gets the weight (cost information used by OSPF or IS-IS) and IP addresses by SNMP. Next, the RMS determines the relationships between NEs using IP addresses and subnet masks. As a result, the network topology can be discovered. After the network topology has been discovered, the RMS specifies all service paths between any two points. The paths have minimum weights of OSPF between each pair of points (shortest paths). In addition, a Dijkstra algorithm (Dijkstra, 1959) is used as the shortest path selection algorithm as well as OSPF.

3 RELATED WORK

Various methods have been proposed to discover the topology and specify service paths in order to manage network resources.

(Siamwalla et al., 1998) proposed a network topology discovery method that does not use SNMP but uses traceroute and ping. However, this method did not describe shortest path specification methods used by OSPF.

((Shaikh et al., 2002) and (Shaikh and Greenberg, 2004)) proposed a method that uses an OSPF message such as LSA. If an RMS uses this method, a Bandwidth Broker can specify every shortest path of OSPF in real time. However, in this method, we need special servers that implement an LSA speaker method and a robust security framework. And this method needs to connect with each OSPF area. For our Bandwidth Broker type QoS-guaranteed service, these costs are large. Furthermore, in their method, a discrepancy between the service path of a real network and the resources stored by a Bandwidth Broker occurs in the calculation time. Rapid convergence technology provided by router vendors has advanced greatly (CiscoSystems, 2003). After a failure occurs, network topology convergence may be possible within in one second. If an RMS starts calculating after failure detection, it cannot eliminate the discrepancies in the process.

On the other hand, if an RMS collects the weights of OSPF or IS-IS, it can specify shortest paths beforehand. In addition, an RMS assumes that each node or link has failed, and calculates shortest paths in the topology without assumed failure points. Therefore it can also store detour paths beforehand. An RMS can switch managed resources to detour paths as soon as failure has been detected and discrepancies can also be minimized. However, the number of assumed failure patterns to calculate all detour paths becomes huge depending on the network scale. So, it is not realistic to store all path data in the database of an RMS or Bandwidth Broker. Furthermore, the calculation of detour paths is especially heavy. In the worst case, the calculation could take several days. Therefore, the service cannot be started quickly.

So, we devised a new detour path calculation method called the "Look-ahead type" detour path specification. If failures occur, we can satisfy both the need to reduce the number of necessary calculations for detour paths and high-speed switching of managed resources in a Bandwidth Broker type service.

4 "LOOK-AHEAD TYPE" DETOUR PATHS SPECIFICATION

In this method, an RMS calculates only shortest paths and "primary" detour paths before service starts. It does not calculate all detour paths. The detour path calculation procedure is shown below. An RMS extracts shortest paths between every pair of nodes, and saves them all in the database. At this time, the information about nodes and links between the starting point S and the destination point D is held as attribute information of the shortest path. We assume that one of these links or nodes breaks down. The shortest path between S-D in the network topology avoiding the assumed failure is recalculated (Figure 3).

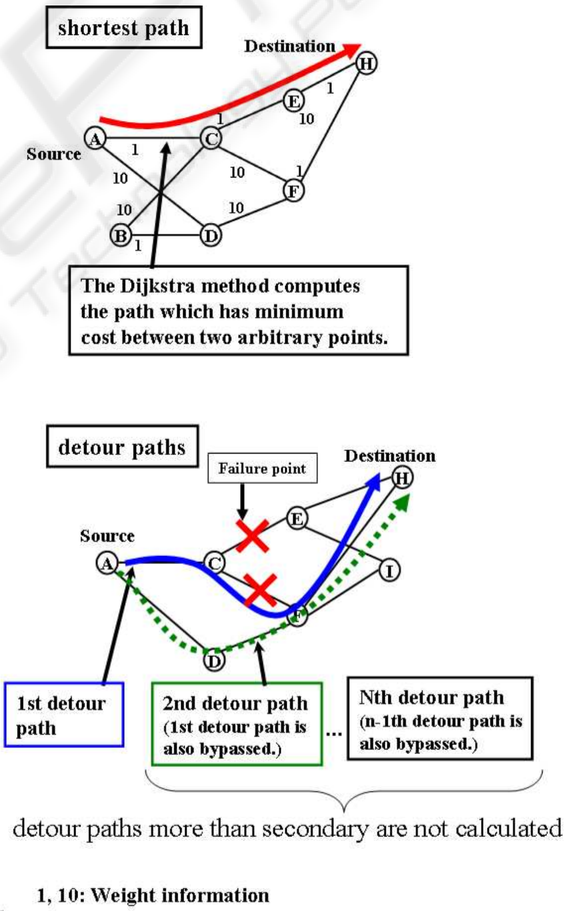

Figure 3: Detour path specification.

This is repeated for all nodes or links. Next, the

RMS calculates the detour paths in the case of multiple link or node failures. Furthermore, this procedure is repeated for all shortest paths. If a selected path produces the same results, the path is not stored. The specified paths when the shortest paths break down are defined as primary (1st) detour paths.

In the stage in which the primary detour path calculations ended, an RMS provides Bandwidth Broker with path information and service starts. Paths that bypass the primary detour path are defined as secondary detour paths. Theoretically an RMS could calculate the secondary detour paths when assuming that the primary detour paths are broken. Likewise, the more-than-third detour paths can be extracted. But in our method, these detour paths are not calculated before service starts (only shortest paths and primary detour paths are calculated), because the detour paths more than secondary are not used at the service start time. Another reason for not calculating detour paths more than secondary is because the load becomes several times larger than for a primary path since the number of failure patterns increases. By not calculating the detour paths more than secondary, we sharply reduce the amount of calculation before service starts.

However, we think the RMS cannot provide QoS-guaranteed services using only primary detour paths in the long-term service employment, because the possibility of serious failure occurring increases and more-than-secondary detour paths are needed for services in long-term service operation. In this case, an RMS may not obtain necessary detour paths without calculating more-than-secondary detour paths. But our "Look-ahead type" detour path specification method definitely provides detour path information about one step ahead using network monitoring. After providing shortest paths and primary detour paths, an RMS continuously monitors the network by ping and trap. If a network failure is detected, the RMS reports the failure point to a Bandwidth Broker. The Bandwidth Broker immediately switches managed resources to detour paths. At this time, the Bandwidth Broker does not interrupt its service because it has already stored necessary paths among the primary detour paths. After informing the Bandwidth Broker, the RMS starts calculating new primary detour paths based on the present network topology existing after the failure. The new primary detour paths are actually included among secondary detour paths at service start. The amount of calculation for new primary detour paths is less than that for all secondary detour paths before the service starts because necessary detour paths are limited by failure. These calculations are performed as background processes by an RMS. Therefore, the current service by a Bandwidth Broker is not interrupted.

In this method, the RMS can achieve a result equivalent to calculating the third and higher detour paths by calculating primary detour paths after a failure. When there is two or more failure, a network topology pattern is changed in accordance with the order of recovery. Therefore, the RMS has to calculate the recovery path with primary detour paths, and the paths are reported to a Bandwidth Broker. The calculation flow of our method for detour paths is shown in Figure 4.

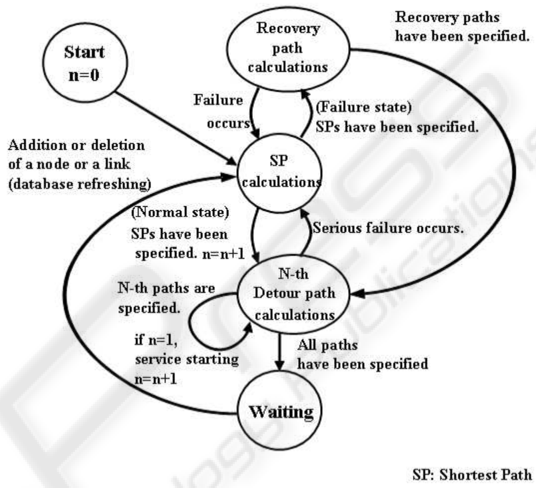

Figure 4: State changes of "Look-ahead type" detour path calculation.

5 EVALUATION

In this section, we evaluate the "Look-ahead type" detour path specification method. The model network of OSPF topology is shown in Figure 5.

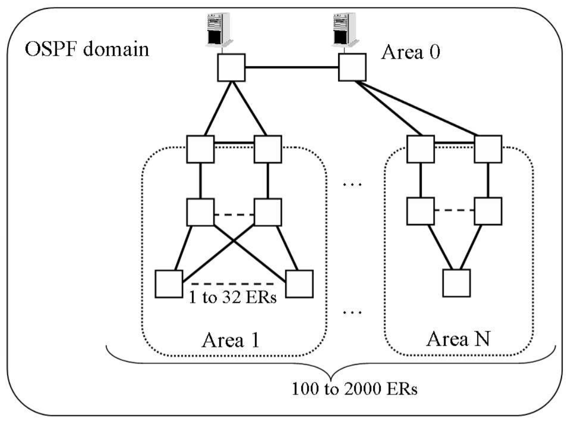

Figure 5: Network model (OSPF topology).

In this network, OSPF areas are directly connected to area 0. We assume the basic topology in each area is a tree type. However, some paths are duplex, and detour paths exist for service redundancy. We verified our method for 100 to 2000 edge routers.

The dependence of the number of links and paths or the number of nodes for the above-mentioned conditions is shown in Figure 6.

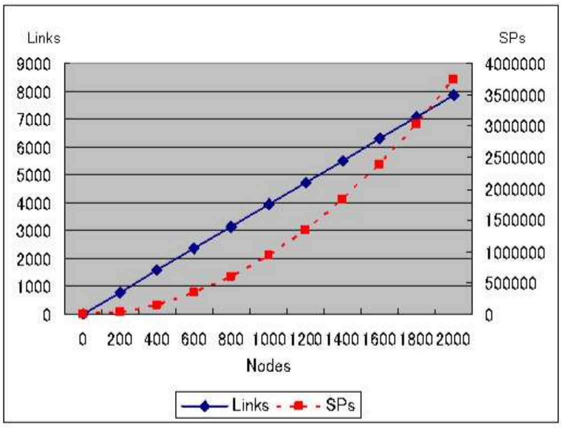

Figure 6: Dependence of the number of links and paths on the number of nodes.

In this simulation, the number of links was almost linearly proportional to the number of nodes, and the number of paths was proportional to the 2nd power of the number of links.

First, the number of paths is shown in Table 1.

Table 1: Number of paths.

ERs	Shortest path	1st	2nd	3rd
100	9,900	31,460	55,730	356,390
1000	999,900	3,909,560	6,848,930	20,431,590
2000	3,998,000	15,818,520	27,696,860	82,859,380

The number of times of the Dijkstra calculation is considered to occupy a large proportion of the path specification processing as shown in Table 2.

Table 2: Number of times of Dijkstra calculation.

ERs	Shortest path	1st	2nd	3rd
100	2,956	11,824	47,296	281,411
1000	35,240	140,960	563,840	3,354,848
2000	79,622	318,488	1,273,952	7,580,014

The detour path specification by assumption of failure patterns is not very efficient because of reachability loss and re-extraction of the same paths. However, the number of calculations is less than the number of paths because the RMS specifies paths inside the OSPF area first. Next, it connects each path between areas. Finally, it determines an end-end path.

The simulation showed that when calculations were performed using a general-purpose PC (CPU: Pentium 4 2.5GHz), the calculation time for deriving about 4 million SPs in a 2000-node network was about 60 seconds. These results show that the Dijkstra algorithm is fast enough for service. And it took 11 minutes to calculate the 15 million primary detour paths. They show that there is no serious influence on the start of service.

However, it will probably be difficult to prepare detour paths beforehand if the "Look-ahead type" method is not used because the calculation time was more than 3 days until the third detour path was completely extracted. Specifying beyond third detour paths takes even more time. When the "Look-ahead type" is used, service can start after 11 minutes. Primary detour paths for the present topology are consistently prepared after service has started. The worst case that we consider is that the discrepancy for re-calculating the shortest paths occurs for about 1 minute in our "Look-ahead type" detour path specification. This is because the discrepancy only occurs in the case where many nodes break down simultaneously and the detour paths more than primary detour paths used by the service are suddenly required. In these cases, you should consider the case where a serious failure, like loss of network connection, occurs.

6 CONCLUSION

We proposed a resource management method for IP networks, called "Look-ahead type" detour path specification. We discussed the advantages and problems of detour path management methods and verified that IP network resource management that includes detour path management is sufficient for practical use.

In addition, each function of a RMS has been developed as a software module that operates on a service management platform called a service resource agent (SRA) (Miyoshi and Kimura, 2002) (Miyoshi et al., 2002) (Figure 7).

A SRA has a general-purpose interface to connect network management systems and network elements. A SRA can collect data to perform service management by SNMP or telnet using this interface. Moreover, the table of a database is designed so that one service path can be managed as one object. We could use these functions without changing a SRA platform and implement a RMS on a SRA as only one function module which calculates shortest paths and detour paths.

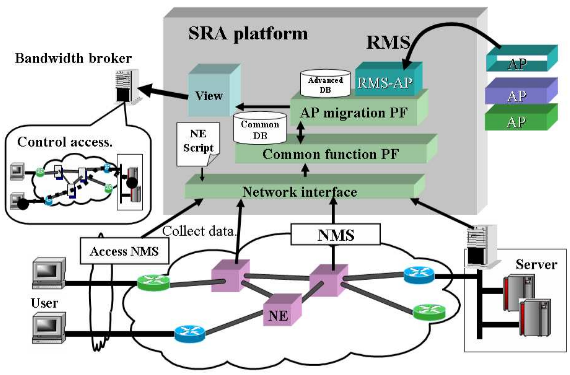

Figure 7: Service management platform.

Even for IP network services, which are best-effort services, the topology and paths can be specified by the method presented in this paper and functions that achieve QoS-guaranteed service can be provided. Our detour path specification method is applicable to various other services, so we want to use it to contribute to the creation of new services.

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