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ON THE IMPLEMENTATION OF DYNAMIC RECONFIGURATION IN TELECOMMUNICATION NETWORKS

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Abstract:
In this paper we summarize our proposed methodology for dynamic reconfiguration of telecommunication networks. This procedure is implemented to achieve network recovery in the case of any failure in the network. We also outline a brief description of path analysis techniques that are considered in the rerouting of Origin-Destination traffic flows and address how these methods are used in the implementation of proposed algorithm

Introduction

Network survivability is the ability of a network to recover from failures [1] and is one of the most important requirements of networks. Here we address dynamic reconfiguration [2,3] as a survivability mechanism. Different techniques may be used for the implementation of dynamic reconfiguration. One of them is based on the simple mathematical modeling of the network (linear programming) [4] which leads to an optimization problem. In general these types of optimization problems are very large in dimension and very hard to solve if any integrality issue is also taken into account. In general real life problems are very large and the associated optimization problems are very complex and hence more time efficient techniques are necessary. In this paper we describe an algorithm based on a simple heuristic where an approach based on sorting out trajectories generated by a subgraph is used. Our preliminary results suggest that this algorithm is faster than previous linear programming techniques. Here we also address important quality of service issues, such as performance, efficiency, scalability and ease of implementation.

This paper aims to address and develop the following issues:

1. Mathematical models for dynamic reconfiguration in the presence of Service Level Agreement (SLA) [5];
2. A conceptual scheme of the proposed algorithm and
3. The software implementation of our methodology (some additional hypotheses are introduced in order to satisfy practical usability of the sofawre).

Definitions, Methods and Software

Dynamic reconfiguration is defined as the capability that can extend or modify long running systems without the need to stop them. Traditionally, most of the work done with dynamic reconfiguration has focused on systems designed with the traditional client/server model.

Survivability can be defined as the ability of a system to complete its mission in whole or in part in a timely manner, despite the failure of some significant elements of the system due to accidents. Information systems survivability is more than just computer security and here we propose to use dynamic reconfiguration schemes as a survivability mechanism.

Modern telecommunication management includes Service Level Agreements (SLAs), which act as implicit penalties and complicate the dynamic reconfiguration problem [6]. We consider the so-called Olympic service that provides three tiers of services: gold, silver and bronze with

decreasing quality. When a failure occurs, the provider needs to reconfigure the network in order to transfer the status of the network as quickly as possible. The main intension is to satisfy traffic requirement constraints considering the first priority to the gold type customers and then to the silver type customers and lastly, if there is any unused capacity left, to the bronze type customers. In the case of network failure, the time for the breakdown is defined a priori for gold and silver flows by SLAs. System provider is liable to pay large penalties if the time limit is exceeded. The time limit for the gold customers is very small and it is larger for silver customers but still not very large. This leads to the following requirements: The process of reconfiguration must have minimal effect on the priority traffic that was not affected by the original failures. The solution time for reconfiguration process should be very small. The latter requires considering simple optimization problems as dimension of these problems might be very high. One of the possible ways to fulfil this requirement is to select a certain subgraph of the main graph as the basis of our optimization and confine the reconfiguration of the entire network to this subgraph only. Through out the rerouting procedure we should try to keep the priority traffic untouched out of this subgraph.
We introduce mathematical models for dynamical reconfiguration based on this idea. Usually short paths are preferred for the routing in the telecommunication networks. However longer paths can also be used in order to provide service for gold and silver customers in the case of failure. We need to compare the potential working/protection paths with different lengths for each Origin-Destination pair in order to gain an overall optimal routing in the network.

We suggest a conceptual scheme of an algorithm for dynamical reconfiguration which is based on the developed approach. This algorithm considers the status of Service Level Agreements and reconfigures the traffic routing in the network in the case of any link and/or node failure. To satisfy the required capacity for the affected traffic, we consider the available residual capacity in the network. If there is not enough residual capacity in the network then we attempt to involve some of the unaffected traffic, taking into account the priorities in terms of Service Level Agreements. We use a projection of the subgraph in order to have minimal possible effect on the priority traffic that was not affected by the failure.

Software

We have developed software based on the proposed algorithm. The following simplifying assumptions have been made to allow us to implement this algorithm. To minimize the effect of the reconfiguration in the whole network we choose a subset of the graph which includes the failed links/nodes and some surrounding element in the network. This selection must be as small as possible to minimize the effect of our reconfiguration on the non-affected traffic and it must be sufficiently large to perform the reconfiguration task (there should be enough unused capacity in the selected sub-graph to achieve significant recovery). The selection of a proper sub-graph is a hard task and an arbitrarily selected one may not be feasible to handle required recovery in the network. We shall consider certain subgraphs of the given graph in order to overcome these drawbacks. To make a better decision we need to take into account the structure of the graph (topological characteristic) and consider only a certain part of the neighbourhood of the broken links or nodes. Possibly we should also consider different neighbourhoods for gold, silver and bronze services.

The optimization problems that were described are of very high dimension for large real-life networks. Indeed the dimension of problem is $O(nm)$ where n is the number of OD pairs and m is the average number of working paths for each OD pair. This complexity figure corresponds to the number of decision variables in the mathematical model of the reconfiguration problem.

The use of a subgraph of a given graph and the potential recovery paths with small order, allows us to gain substantial reduction in the dimension of linear programming problem. As the result of this the solution time of our problem can be reduced significantly.

Further we need to work out routines to describe rules for finding the subgraph and the set of working paths generated by this subgraph. These rules should take into account the structure of the graph, position of the broken links/nodes, magnitude of the failure and the traffic conditions. It is necessary to introduce the notion of the order of a path, which is convenient tool for selection of working paths (Fig. 1).

Paths analysis

Since the process of reconfiguration must have minimal effect on the priority traffic that was not affected by the original failures, we suggest to consider a reconfiguration only for paths of a certain subgraph which can be different for gold, silver and bronze customers. In choosing the working/protection paths, we will consider only such paths which go through subgraph only once because the analysis of paths which go through subgraph more than once is difficult. In some occasions we need to partition long paths into some short paths which go through subgraph only once and examine them separately.

In Fig. 1 the path K→M→P passes twice through the subgraph. We divide this path into two parts: K→M and P→M, where both of them pass through the selected subgraph (the inner graph in this figure) only once.

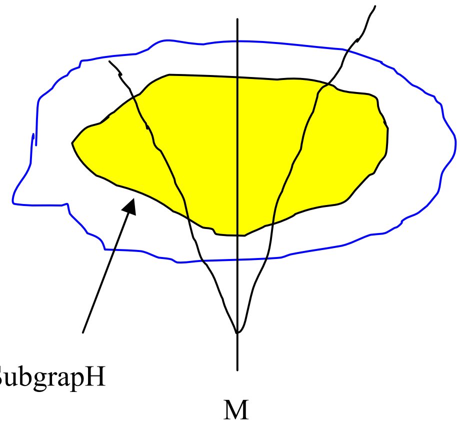

Figure 1. Path partition in the selected subgraph

Reconfiguration

Two different approaches for dynamical reconfiguration can be discussed: with and without penalization. The approach with penalization does require determining the priority list of customers with the reduced ODs traffic demands. In this method the network provider must pay penalty equivalent to the amount outlined in the agreement for any minute of service violation. Reconfiguration of the network in the absence of penalty is very easier task comparing to one with penalty.

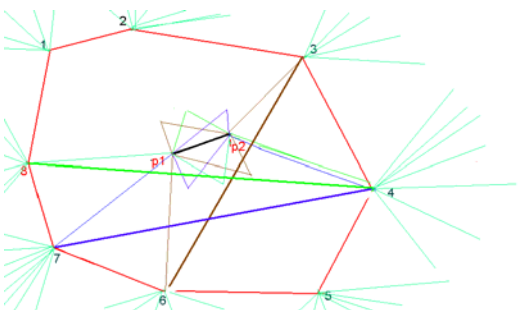

Figure 2. Localization of the optimization problem by boundary nodes

Conclusion

We suggest using the process of reconfiguration which consists of the following steps:

- For a given network and failure scenario, select a minimal subgraph containing the failure elements with small neighborhood;
- Find the potential working/protection paths in this subgraph
- Using a subset of paths found in the earlier step; generate the mathematical model for network reconfiguration. This would result in a simple but very large optimization problem;
- Solve the resultant optimization problem. In the case that it is not feasible, extend the boundaries of the subgraph and expand it and then repeat the modeling and solution steps.

It is assumed that the price metric (cost function) and the penalty parameters are known. The choice of subgraph can be reduced to the choice of an order of a neighborhood of the broken link. Choice of sets of paths can be reduced to the choice of lengths of these paths and their order separately for gold, silver and bronze customers.

Description of a set of paths of the initial graph G that can be used for reconfiguration is given together with the following assumptions:

1. The description of a subgraph for reconfiguration should be given;
2. Choice of an extended set of working paths should be defined (the maximal order of paths and associated lengths should be given separately for gold, silver and bronze customers);
3. The SLA status should be known at each instance.

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