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CHALLENGING ISSUES IN DYNAMIC RECONFIGURATION OF TELECOMMUNICATION NETWORKS

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Abstract:

For the last quarter of a century understanding of the nature of telecommunication network traffic has been considered as an important research topic. Any well-designed recovery strategy has to take into account the different resilience requirements of the single traffic flows in order to avoid excessive usage of bandwidth for standby links. Here we discuss the issues of a reconfiguration procedure in order to perform network recovery in the case of any failure scenario in the telecommunication networks. We explain the complexities arising in the real life application and propose an optimization technique in order to minimize the size of the optimization problem in the process of reconfiguration. Our suggestion to achieve this is to find the minimal sub-graph surrounding the failure region that contains the required unused capacity to perform network recovery task.

Introduction

Network flow problems arise in the design and analysis of telecommunication systems, neurological systems, tanker scheduling problems and a variety of other areas. Generally the configuration (topology) of the network is constrained by several factors that depend on the particular routers scheme, maximum through-put, number of virtual channels, etc. Here we introduce a typical survivable network design problem and propose a methodology to perform dynamic alternative routing to achieve network reconfiguration in the case of certain failures [1] in the system.

We outline the following steps as a procedure to study, analyze and recovery in the case of any failure scenario in the telecommunication network.

1. Rerouting—to find alternative routes, if one or more links or nodes fail in the network. Our motivation in this work is to achieve network reconfiguration with the minimal effect on the non-disturbed traffic in the network. To achieve this we confine our reconfiguration process by defining some inner graph and its boundary. The intension is to perform the capacity design process only in the localized sub-graph of the network. This would lead to the minimal rerouting of the traffic in the network and would limit its effects only to the defined sub-graph.
2. Clustering—this could be the case in which we are dealing with decomposable network.
3. Network capacity design—which is the final stage of our reconfiguration strategy.

A survey titles as "Network Infrastructure Trends and Issues" by Sunbelt Software in collaboration with Yankee Group analysts, Zeus Kerravala and Laura Didio uncovered that two-thirds of the 250 IT administrators polled worldwide said their companies do not implement configuration management software to track changes in the network and/or systems errors - despite the fact that 70% of companies experience at least one-to-two network outages per month [2].

One of the main obstacles to reach a high level market is - how to reorganize traffic in the case of failure in telecommunication network? The long breakdown will push some customers to change the provider network; there is also a profit loss due to breakdowns which can be considered as a certain implicit penalty in the process of optimization and reconfiguration.

To reorganize traffic by using new routes we should have a flexible routing strategy. The goal is to create a routing behaviour that is flexible, to reorganize traffic in case of partial failure, to incorporate new routes and even to allow other telecom providers to connect their networks to the system despite of very large network dimensions. For example, the Swedish telephone backbone today consists of about ten thousand routers that route the traffic between towns. Consumer agents will buy traffic at the market for prices that determined by the current traffic and congestion levels in the network.

SLA

Modern telecommunication management takes account of Service Level Agreements (SLAs) [6] between the service provider and the users, which allows managing the service effectively while delivering end-to-end QoS service to the customers. SLAs are a strategic tool for all services providers (particularly IT) on the way to business achievement.

According to research firm [2], most suppliers lose around 16% of their customers each year and nearly 97% of companies with more than 2500 employees require SLA network availability. Without SLA on the table, any technology based support service could be accused of being insensitive to the requirements of its customers, or customers of a support service may have unrealistic expectations of the services.

Hence it is important to implement an agreement that can prevent disputes between customers and suppliers and create harmony between parties. SLA can justify investment and identify the "right: quality of service" [7]. Potentially, SLAs could be based on Business Process Modelling (BPM). Usually SLA for complex services is specified by writing down a set of rules, which are based mostly on the experience of the provider. The idea is to combine SLA with concepts of workflows used in BPM.

The knowledge on design and management of workflows can be used to specify a SLA, actively supporting the operation and usage of complex services. The complexity of the IT services is growing and to specify the requested service, customer and service provider sign a service level agreement that defines the functionality of the service and the required service level. The term of management means the service management crossing the domain boundary between customer and provider.

Due to SLAs the dynamical reconfiguration issue becomes more complicated as different types of customers should be taken into account. In particular, the breakdown time for the so-called "gold" customers should be kept very small. This also implies that the process of reconfiguration must be quite quick.

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 network optimization required for reconfiguration, should be very small.

The latter requires considering simple optimization techniques (for example, linear programming without integer variables).

An efficient and effective management requires fast reconfiguration process, and also the minimal possible effect on the priority non-affected traffic. To achieve this we need an advanced mathematical rerouting algorithm. However based on the physical topology of the network, there may be a number of mathematical models that could be useful. Linear programming and network flow based methods are the well known methodologies from application points of view [3].

In this paper we discuss a graph based modelling methodology for failure recovery problem in the networks. We propose a special graph theoretical approach which is a combination of some simple network flow problems and our localization technique. A graph is a mathematical representation of a network. Although a graph is simpler than the network itself, but it does reflect all features and characteristics of the network. Please note that any given network can be transformed to a graph and any kind of the network transaction could be considered as some manipulation of the graph that has the same structure. The technical term referring to the similarity of the characteristics of a network and its representative graph that are structurally the same or equivalent, is called "*isomorphic*".

In the case that our reconfiguration [4,5,8] network could be modeled as a linear programming one, then a well-known solution technique like the simplex algorithm can be used to solve the problem. As the size of the real-life networks are very large, any kind of further complication like introducing integer or non-linear variables in the model for failure recovery would not be desirable.

Here we consider that the graph G=<V, E> represents our network, where V is a finite set of nodes (vertices or points) and E is a finite set of links (edges). Further we assume that all links are bi-directional.

In order to develop a solution methodology to our reconfiguration problem, we need to establish a graph notation (Fig. 2) to define the network; service and traffic parameters or attributes (sets of arguments) and we need to describe a management policy as a set of operations applied on the graph. We construct a model for reconfiguration that takes into account these requirements. Later we propose a conceptual scheme of an algorithm for reconfiguration which is based on these models.

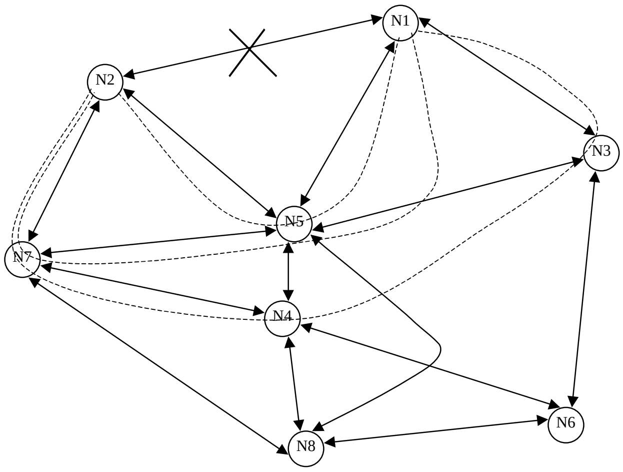

Figure 2. Graphical representation of a failure scenario in the network: The link with cross sign is failed and the potential protection or recovery paths are drawn in dotted lines.

The concept of survivable network design and network recovery in the case of any link/node failure is similar to the network design problem where the allocation of extra protection [8] capacities in the network elements is the concern. While the former one is a network structural design problem and is mainly based on some finite typical failure scenarios, the latter one addresses the real-life events that may be correspond to some scenarios that possibly never have been considered during initial network design process.

Considering survivability issues, a typical telecommunication network is generally dimensioned to satisfy all Origin-Destinations (ODs) traffic demands for a given pattern of the traffic load in the case of one or more node or link failures in the network. In practice, it is not possible to take into account, all the possible traffic patterns and failure scenarios in the design of survivable networks. As a matter of fact in the real life, during the operation of the network, the pattern of the traffic in the network may change radically over time and then the existing network may not satisfy all ODs traffic in the case of certain node or link failures. In such situations, the strategy would be to satisfy the required traffic somehow in the network by performing a process of reconfiguration and re-optimization in the network.

There are two issues here that should be taken into account. The first one is the size (dimension) of the optimization problem which can be very high for real networks. The second issue is the effect of the optimization process for reconfiguration which might lead to a traffic rerouting with significant effect on the non-affected traffic. This is something that network providers hesitate to do.

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 of the network. At the same time the selected sub-graph must be sufficiently large to allow the network provider to perform the reconfiguration task (there should be enough unused capacity in the selected sub-graph to achieve significant recovery). This is the logic behind our fault localization scheme in this paper. 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 under consideration and consider only a certain neighborhood 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 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 of a small order allows us to gain substantial reduction in the dimension of linear programming problem that is used for the reconfiguration. As the result of this the solution time of our problem can be reduced significantly.

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.

Conclusion

We introduced a reconfiguration methodology based on fault isolation or localization to provide recovery in the case of nodes/links failure in the network. Fault localization minimizes the effects of our optimization in the process of reconfiguration on the non-affected traffic part of the network. This process fits with the practical limitations and constraints in the real life scenario.

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