Shortcut Span Protection

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1. Introduction

Designing resilient networks has been in focus of research and industry for some years now, resulting in a large variety of both well-known and experimental resilience provisioning mechanisms. Many of these studies focus on providing networks with the least amount of capacity possible to fulfil the demanded level of protection.

2. Mesh Protection Methods

Two well-known methods for providing resilience in mesh networks are span protection and path protection. In span protection, the entire traffic is re-routed locally between the nodes adjacent to the failed span, meaning that the end nodes of a connection are unaware of the failure. This results in a short notification time, but generally also means a longer protection path.

In path protection, the affected connections are re-routed on an end-to-end basis, where an individual backup path can be found for each connection. This approach results in high resource efficiency and does not necessarily result in a backup path of higher cost compared to the original working path. Restoring connections between their end-nodes requires considerably longer notification times than in the local span protection approach. Since each affected connection can be re-routed individually, a large amount of complexity is added to the network.

A more recent method is termed local-to-egress or local backup dynamic protection, described in [1] and [2] respectively, where the traffic is re-routed between the upstream node adjacent to the failure and the egress node of the connection. This combines the advantages of the two aforementioned methods, specifically the short failure notification time and the freedom of finding a backup path that does not need resume the original path locally. The different protection methods are illustrated in Figure 1.

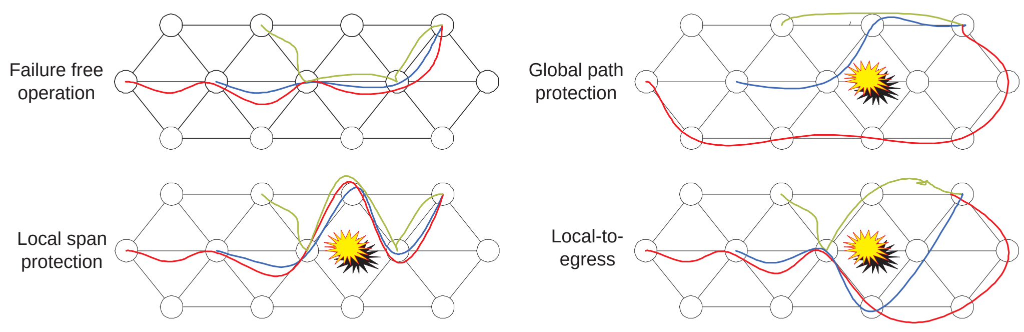

Figure 1: Protection methods for mesh networks

3. Related Work

The local-to-egress method was further studied in [3], where an arc-flow linear program to obtain optimal working and backup paths in mesh networks was provided. In that model, each affected connection was re-routed individually between the local failure adjacent node and the egress node. The model was applied to small networks and the finding was that the gain in capacity was rather small (order of a few percent).

We question whether the small gain in capacity justifies adding the complexity of fully individual connection re-routing in the local-to-egress protection method. Especially in core networks, where the trend is going towards having the complexity at the edge nodes of a network, the core routers should only have to deal with simple decisions. Furthermore, with the prices for fiber (capacity) dropping [4], capacity usage will become a less important factor for deciding which protection method should be employed, whereas complexity and speed combined with the manageability of the method is expected to be given higher priority in the decision process.

4. Model

To reduce the complexity of the protection method and the restoration time, we want to investigate a variation of the local-to-egress protection method, which we have termed, Shortcut Span Protection (SSP). In SSP, the traffic is bundled between the failure adjacent node and the egress node if several affected connections have the same destination node. The method is illustrated in Figure 2. The advantage of the proposed method lies in a less complex (and therefore faster) decision-making and routing process, resulting in less complex core nodes. The SSP is expected to require more capacity than path protection, but less than span protection.

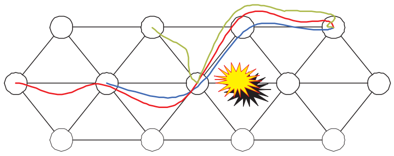

Figure 2: Shortcut Span Protection (SSP)

We will now describe a Linear Programming (LP) model for the joint routing and protection problem for the SSP protection scheme. Given a network with N nodes indexed by i, j, k, l, q, r, a number of oriented links L, indexed by (ij) and by (qr), indexing the normal links and the failed links respectively. The cost of the link is given by the constant $c_{(ij)}$. The communication demand, i.e. the number of oriented circuits which should be established between the nodes k and l is given by the constant $D^{(kl)}$. The model is a so called link-path model and it contains 3 types of variables: $x_p^{(kl)} \in R^+$, the non-failure flow paths between node k and node l, $y_p^{(qr),l} \in R^+$, the failure recovery flow from the start node q of the failed link qr to the end node of the flow l, the required **non-oriented** capacity $z_{\{ij\}} \in R^+$. The non-failure paths are defined by the incidence matrix $A_{p,(qr)}^{(kl)} \in \{0,1\}$ and the restoration paths $B_{p,(ij)}^{(qr),l} \in \{0,1\}$.

Shortcut span protection link-path LP model minimize:

$$\sum_{\{ij\}} c_{\{ij\}} \cdot z_{\{ij\}} \tag{1}$$

subject to:

$$\sum_p x_p^{(kl)} \geq D^{(kl)} \quad \forall (kl), \tag{2}$$

$$\sum_p y_p^{(qr),l} - \sum_k \sum_p A_{p,(qr)}^{(kl)} \cdot x_p^{(kl)} \quad \geq \quad 0 \quad \forall (qr), l, \tag{3}$$

$$z_{\{ij\}} - \sum_{(kl)} \sum_p [A_{p,(ij)}^{(kl)} + A_{p,(ji)}^{(kl)}] \cdot x_p^{(kl)} \tag{4}$$

$$- \sum_l \sum_p [B_{p,(ij)}^{(qr),l} + B_{p,(ji)}^{(qr),l}] \cdot y_p^{(qr),l} - \sum_l \sum_p [B_{p,(ij)}^{(rq),l} + B_{p,(ji)}^{(rq),l}] \cdot y_p^{(rq),l} \quad \geq \quad 0 \quad \forall \{ij\}, \{qr\},$$

$$x_p^{(kl)}, y_p^{(qr),l}, z_{\{ij\}} \in R^+ \tag{5}$$

The shortcut span protection LP model consists of an objective function (1), demand constraints (2), protection constraints (3) and capacity constraints (4) and domain definitions (5). The objective function (1) measure the cost of the necessary capacity in the network. The demand constraint (2) ensures that the circuits are established in the non-failure situation. The protection constraint (3) ensures that protection paths are assigned to reroute communication in case of any single link failure. Finally constraint (4) ensure that enough capacity is assigned to the links to cover all single link failure situations.

The shortcut span protection LP model corresponds closely to the model presented in [3], except it is formulated using paths. We will generate these paths using column generation. Afterwards, given both the non-failure paths and the protection paths, we will solve a slightly different problem, where we only will allow one backup path for switch q, for oriented link (qr) to demand end node l. We will hence add a binary variable $u_p^{(qr),l}$, and the constraints given (6) (7) (8) below.

$$y_p^{(qr),l} \quad \leq \quad M \cdot u_p^{(qr),l} \quad \forall (qr), l, p \tag{6}$$

$$\sum_p u_p^{(qr),l} \quad = \quad 1 \quad \forall (qr), l \tag{7}$$

$$u_p^{(qr),l} \in \{0, 1\} \tag{8}$$

References

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