行政院國家科學委員會專題研究計畫成果報告

整合性高速網路軟體工程環境之研究與設計—經由高效能傳輸系統對高速網路做符合性與效能上的測試

Conformance and Performance Testing of High Speed Network Protocol Over High Performance Transport Protocol

計畫編號：**NSC 87-2213-E-009-019**
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一、中文摘要

在符合性與效能上的測試的領域中，網路的可靠度分析扮演著非常重要的角色。在這個計畫裡，我們對於兩個網路可靠性分析的問題作深入的研究：端點間的可靠度 (Terminal-pair Reliability）及可靠度的邊際效益 (Marginal Reliability Importance)。TR用以決定在此網路中兩端點間可連通的機率值。而MRI是指變更某一條連線的故障率時，TR隨之改變的速率值。 它反映了每一條連線對網路可靠度的貢獻量。 在這份報告中，我們首先提出一個新的簡化法法：三角簡化法，這個轉換的計算複雜度是$O(1)$。對於第二個問題，計算一二網路的MRI值是NP-Complete，在這份報告中，我們介紹一種新的網路群：reducible$^+$ networks；並提出一個兩階段的演算法段計算reducible$^+$ networks的MRI值。段用這個演算法，計算reducible$^+$ networks的MRI值可以在線性時間內完成。

關鍵詞： 端點間可靠度 成TR），分成演算法，網路簡化技術， 可靠度的邊際效益，可簡化網路。

Abstract

In the area of conformance and performance testing, network reliability has been playing a crucial role. In the project, we aim at the study of two reliability problems: Terminal-pair Reliability (TR) and Marginal Reliability Important (MRI). TR determines the probabilistic reliability between two nodes (the source and sink) of a network, given failure probabilities of all links. MRI of a link with respect to TR is the rate to which TR changes in association with the modification of the success probability of the link. It is a quantitative measure reflecting the significance of the individual link in contributing to TR of a given network. In this report, we first propose a new reduction axiom, referred to as *triangle reduction*. The computational complexity of the transformation is as low as $O(1)$. The computation of MRI for general networks has been shown to be an NP-complete problem. In the report, we also introduce a new set of networks, *reducible$^+$ networks*, which can be fully reduced to source-sink networks by the triangle reduction axiom.

For efficient computation of MRI for reducible$^+$ networks, we further propose a Two-Phase algorithm. We show that the Two-Phase algorithm yields a linearly bounded complexity for the computation of MRI for reducible$^+$ networks.

Keywords: Terminal-pair Reliability (TR), Partition-based Algorithm, Network Reduction Technique, Marginal Reliability Importance (MRI), Reducible Network

二、 Motivation and Objective

In the area of conformance and performance testing, network reliability has been playing a crucial role. There are two major problems concerned: (1) computation of the TR [1-6] of a given network, and (2) selection of a link in a given network to be improved achieving maximal reliability gain.

It has been shown that TR can be effectively computed by means of the network reduction technique [1-4]. Existing reduction axioms [1-3], unfortunately, are limited to trivial rules such as valueless link removal and serial-parallel link reduction. For the computation of MRI [7-10], it has been shown to be an NP-complete problem [8].

The goals of the report are two-fold. The first goal is to propose a novel reduction axiom, referred to as *triangle reduction* [11,12]. With the triangle reduction axiom, the number of subproblems generated by partition-based TR algorithms is greatly reduced. Thus, the computation of TR can be more effective. We further introduce a new set of networks, *reducible$^+$ networks* [13], which can be fully reduced to source-sink networks by the triangle reduction axiom, in addition to the six reduction rules. The second goal of the report is to propose a Two-Phase algorithm [13] for effective computation of MRI for reducible$^+$ networks.

三、 Approach and Results

The triangle reduction axiom basically transforms a graph, in which the source is only adjacent to two one-way or two-way connected nodes, forming a triangle subgraph, to a simpler graph with the link(s) incident with the two nodes removed. The resulted success probabilities of the corresponding links, connecting the source to the two nodes, are reassigned via closed-form equations [11,12]. The computational complexity of the transformation is as low as $O(1)$. Incorporating the triangle reduction axiom, we prove that the number of subproblems generated by partition-based TR algorithms, *eq O\(\(\F(1+\R(5),2)\)\S\UP3(n)\).*

With experimenting on published benchmarks and random networks, the experimental results [11,12] demonstrate that, incorporating the triangle reduction, the path-based [3] (cut-based [1,2]) partition TR algorithm yields a substantially reduced number of subproblems and computation time for all (most of the) benchmarks and random networks. The improvement of path-based partition TR algorithm in both performance metrics increases with the link degree of the network, while the improvement of cut-based TR algorithm is almost irrelevant to the link degree. In addition, even though path-based TR algorithm was shown in literature [2] to exhibit much poorer performance than cut-based TR algorithm, path-based partition algorithm with triangle reduction axiom achieves surprisingly better performance under sparse networks.

For effective computation of MRI for reducible^{+} networks, we further propose a Two-Phase algorithm [13]. The algorithm performs network reduction in the first phase. In each reduction step, the algorithm generates the correlation, quantified by a *reduction factor* [13], between the original network and the reduced network. In the second phase, the algorithm backtracks the reduction steps and computes MRIs, based on the reduction factors generated in the first phase and a set of closed-form TR formulas [13]. The Two-Phase algorithm, as will be shown, yields a linearly bounded complexity, $O(m)$.

四、 **Merit Review of the Project**

In terms of technical superiority, our approach offers more effective computation of TR and MRI, compared to the existing TR and MRI algorithms. In terms of publication, a simplified version of the triangle reduction axiom has been published in Proc. of ICC'98 and accepted by the international journal on Computer and mathematics with Application. A simplified version of the computation of MRI has also been accepted by Proc. of ICC'99.

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