Adaptive Algorithms for Routing and Traffic Engineering in Stochastic Networks

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Abstract

In this paper we report some of the research endeavors we are embarking on as part of the Doctoral research of the first author. We have already completed an investigation of some of the existing algorithms in the areas of Network Routing and Traffic Engineering, and we propose superior algorithms that would adapt to the changes in the environment in which they operate. In this attempt, we intend to use the theory of Learning Automata (LA) (Narendra and Thathachar, 1989; Obaidat *et al*. 2002) to address the problems we are investigating.

Introduction

The primary goal of the proposed Doctoral research is to address some of the (serious) shortcomings present in existing Network Routing and Traffic Engineering Algorithms. We also hope to propose theoretically and empirically superior algorithms using suitable Artificial Intelligence (AI) techniques that would adapt to the changes in the environment in which they will operate. We propose to use LA to tackle these problems.

LA (Narendra and Thathachar, 1989; Obaidat *et al*. 2002) have been traditionally used to model biological learning systems. They have also been used for learning an optimal action out of several possible actions, which a random Environment offers. Upon choosing an action the learning automaton is either rewarded or penalized by the environment with a certain probability. As time progresses, the automaton eventually attempts to choose the best possible action. Learning is accomplished by actually interacting with the Environment and processing its responses to the actions that are chosen, while gradually converging toward an ultimate goal. The learning loop involves two entities, the *Random Environ*ment (RE) and a *Learning Automaton*.

Because of the vastness and diversity of the problems in the area of Networks, in the proposed research, to start with, we plan to address the following fundamental, yet challenging problems.

Dynamic Algorithms for Single Source Shortest Path Tree Computation

The Single Source Shortest Path Problem consists of finding shortest paths from one node to all others in a network. This problem becomes interesting in dynamic scenarios where the topology and structure of the network constantly changes – i.e., the network links are inserted and dropped-drown from the graph, and the link-costs are continuously randomly changing. Several research papers exist in the literature for solving the problem in scenarios that are not very realistic in computer networks. The relatively difficult, but more realistic network scenarios are fully dynamic, i.e., where the routing algorithms should handle multiple heterogeneous changes in the structure of the networks, besides the changes in the link-costs. This has received very limited attention by researchers (Frigioni *et al*., 2000; Ramalingam and Reps, 1996).

Prior to our work, there has been no solution for the dynamic single source shortest path problem using LA. In the past, LA solutions of various other problems have shown superior results. In this regard, we have already investigated this problem, and proposed superior LA-based solutions, when compared to the currently available ones. Our algorithms (Misra and Oommen, 2004) are the best known so far for solving the dynamic single source shortest path problem. The algorithm has been rigorously experimentally evaluated, and has been found to be a few orders of magnitude superior to the algorithms available in the literature. In particular, it can be used to find the shortest path within the "statistical" average network, which converges irrespective of whether there are new changes in link-costs or not. On the other hand, the existing algorithms will fail to exhibit such a behavior and would recalculate the affected shortest paths after each link-cost update. We have also designed and tested a new set of learning algorithms for maintaining software path routes using the theory of Generalized Pursuit Learning that pursues a set of actions at any time instant, instead of a single action. This set of algorithms has also demonstrated superiority of performance, when compared to the other algorithms.

Dynamic Algorithms for All-Pairs Shortest Paths Problem

The problem of determining the All-pairs Shortest Paths Problem concerns finding shortest paths between all-pairs of vertices in a network. As in the previous problem, we propose to solve, using LA, the dynamic version of the problem where the topology and structure of the network constantly change when links go up and down randomly in a network, and the edge weights change randomly. Two popular existing dynamic all-pairs shortest path algorithms are described in (Cicerone *et al*., 2003; Demetrescu and Italino, 2003).

Adaptive QoS Routing Algorithms

Quality of Service (QoS) Routing Algorithms are concerned with selecting routing paths while meeting strict end-to-end service requirements involving resource constraints, while achieving optimum throughput in the network. Two basic considerations in QoS Routing in integrated services packet switched networks concern: (1) routing traffic with bandwidth guarantees, and (2) routing traffic with delay guarantees. Some of the algorithms proposed for solving the latter problems are: Widest-Shortest Path (WSP) (Guerin *et al*., 1997), Shortest-Widest Path (SWP) (Wang and Crowcroft, 1996), and the Shortest-Distance Path (Bellman, 1958; Dijkstra, 1959) solutions.

We propose to solve this problem using LA under dynamic scenarios where the network links constantly go up and down, and the link-costs change randomly.

Network Traffic Engineering Algorithms

The above-mentioned QoS Routing algorithms, viz., WSP, SWP, do not provide routing decisions considering the underlying traffic distribution in a network, and therefore can lead to under-utilization of network resources. Two recent Traffic Engineering Algorithms, which have gained widespread popularity are (1) Minimum Interference Routing Algorithm (MIRA) (Kodialam and Lakshman, 2000), and (2) Profile Based Routing (PBR) (Suri *et al*., 2003). Both the algorithms are complex and are computationally intensive and are based on minimum-interference theory, and the multi-commodity flows.

In this research, we also propose to devise a relatively simpler LA-based Traffic Engineering algorithm for enabling the dynamic routing of bandwidth-guaranteed flows in carrier and ISP networks. The devised algorithm will hopefully perform better than the existing algorithms in terms of the amount of bandwidth routed, the number of requests rejected, and the amount of link capacities wasted.

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