Computers and Electrical Engineering 38 (2012) 1433–1443

Contents lists available at SciVerse ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

Design of multi-path data routing algorithm based on network reliability ☆

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ARTICLE INFO

Article history:
Received 23 February 2010
Received in revised form 12 April 2012
Accepted 13 April 2012
Available online 28 May 2012

ABSTRACT

Data routing through an interconnected network is important and this paper addresses the design of a multi-path data routing algorithm based on network reliability. Generally, multiple routes for a given source–terminal pair exist in a data network and the best possible route based on network metrics like hop-count, delay, traffic, queue, etc. is selected by a routing algorithm. Since network reliability incorporates all these metrics, the routing decision based on reliability seems to be the best possible option and a distributed routing algorithm based on the source–terminal (s–t) path reliability has been proposed in this work. Each node in the proposed routing generates an adjacency matrix of a network graph by periodically exchanging connection information with the adjacent nodes and selects multiple routes based on reliability of the paths. We propose an implementation of a two-path routing algorithm that instead of one includes two next-hop nodes in each node's routing table. An example is given for further illustration of the proposed algorithm.

1. Introduction

The essence of routing is a simple question – What is the best way to reach from one place to another? But it includes the hurdles embedded in modern intra-domain routing protocols. At the core of this belies the fact of continuous change of network topology. Routing for a static network is trivial. It incorporates a table of routes calculated once for each destination. But the scenario for most of the real networks is different. The network links go up and down at various instances of time resulting to a different topology from the previous one. This requires the nodes to recalculate their routes. This problem in turn can be boiled down as the size of the network grows. With the increase in network size, the change in topology also increases and this change can become problematic, because for a large network the routing updates will be generated more often. This in turn necessitates more frequent route updates and route re-computation. Thus, every router in the network has to bear the cost. This means the most resource constrained router has to effectively determine all the routes. Moreover, the above scenario gets worsen if routing is based on single path. Major routing schemes typically focus on discovering a single optimal path for routing according to some desired metric. These metrics mainly include hop, distance, speed, delay, cost, etc. Accordingly, packets are always routed over a single path, which often results in substantial waste of network resources. An alternate approach is multi-path routing. It distributes the packets among several "good" paths instead of routing all the packets along a single "best" path.

Multi-path routing can be fundamentally more efficient than the currently used single path routing protocols. It can significantly reduce congestion in hot spots by deviating traffic to unused network resources. This improves network utilization and provides load balancing [1], thereby improving the response time. Moreover, congested links usually result in poor performance. For such circumstances multi-path routing can offer steady and smooth data streams [2]. Multi-path routing algorithms that optimally split traffic between a given set of paths have been investigated in the context of flow control in [3–5].

☆ Reviews processed and approved for publication by Editor-in-Chief Dr. Manu Malek.

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0045-7906/$ - see front matter
http://dx.doi.org/10.1016/j.compeleceng.2012.04.013

Yet, the selection of the routing paths is another major design consideration that has a drastic effect on the resulting performance. Although many flow control algorithms are optimal for a given set of routing paths, their performance can significantly differ for different sets of paths. Therefore, two key questions that arise in multi-path routing are how many paths are needed and how to select these paths. Clearly, the number and the quality of the paths selected dictate the performance of the multi-path routing scheme. There are several reasons why it is desirable to minimize the number of paths used for routing. The significant overhead associated with establishing, maintaining and tearing down a path is the prime reason. Also the complexity of the scheme that distributes traffic among multiple paths increases considerably as the number of paths increases.

Previous studies and proposals on multi-path routing have focused on various parameters including random path selection, latency, traffic, throughput and many more. But none of them has considered reliability as one of its parameter whereas reliability is an important performance criterion of communication networks. In [6] Nelakuditi and Zhang have proposed a hybrid approach where traffic is proportional among the paths. Their technique uses globally exchanged link state metrics for identifying a set of good paths and locally collected path state metrics for proportioning traffic among the selected paths.

More recent P2P applications such as Skype use automatic path selection. Skype [7] claims to keep multiple connections open and dynamically chooses the "best" path in terms of latency/quality. Bit torrent [8] maintains four active paths with an additional path periodically chosen at random together with a mechanism that retains the best paths as measured by throughput.

Recently a number of distributed routing protocols are proposed and some of them are now introduced. A scalable distributed routing protocol based on data-path services is proposed in [9], where routing is done by dividing services among network routers and establishing an optimal route such that (i) Services for given connection requests are executed in a given order, (ii) source–terminal pair path-cost is minimum and (iii) service processing cost is minimum. It proposes a new network architecture consisting of distributed Service Matrix Data Structure to distribute the services among routers, Distributed Service Matrix Routing (DSMR), Distributed Service Routing Protocol (DSRP) and a control plane for implementation of the routing protocol. A generalized distributed path computation technique is proposed in [10] that removes routing loops and count-to-infinity problem occurring in any distributed routing protocol like distance vector routing protocol. It uses a DIVs (distributed intermediate variables) algorithm, which is not a routing algorithm but runs on the top of any distributed algorithm for enabling distributed, light weight loop-free path computation. The basic idea of DIV algorithm is that each node is assigned a value for each destination of the network based on different schemes, for example, cost-to-destination and each node must select a successor node having lower assigned value (a node, which does not have a path to destination, must assign infinity value). It is claimed that DIV algorithm outperforms many loop preventing techniques and has the ability to maintain path during transition. In [11], an efficient distributed routing algorithm is presented based on locally responsive maximally distributed routing policies, which split the data inflow in a non-destination node among the outgoing links as a function of the current traffic density of the network. For this, it proves the existence of a globally attractive limit flow in a network under locally responsive routing policies and the locally responsive distributed routing polices are maximally robust as the resilience of the network coincides with the min-cut capacity of the network.

In recent times, the cloud-based routing and the application-aware routing are two emerging trends for implementing large scale networks to provide cloud computing and the flexible multimedia services to the users. The cloud computing is a computing environment that provides on-demand computation resources and software through Internet on pay basis and allows users to grow/shrink computation resources as needed and recycles among users. On the other hand, the multimedia services mean to design a multimedia network, where context-aware routing would be made to meet the growing demand for emerging of variety of multimedia end heterogeneous equipments in the network. These fields are new and in the growing phase, some of the routing techniques proposed are described now. An elegant technique based on Transit Portal (TP) to control routing in cloud service is proposed in [12]. The TP provides transparent connectivity between clients and Internet Service Providers (ISPs), where each client network with one layer-2 link and a Border Gateway Protocol (BGP) session to an upstream ISP terminates at TP, and the TP with one layer-2 link and a BGP session terminates to each upstream ISP. The TP acts as a tunnel through which multiplexed data packets and BGP messages for client networks are transmitted. The TP is also useful for application-aware routing, where it can make service-aware routing decision and can re-route clients in different data centers based on the change of users' demand. An application-aware routing protocol (AARP) is proposed in [13] that establishes logical connections through application layer resources like bridges, converters to perform bridging and/or format/rate conversion, respectively, where a logical connection consisting of one or more actual network layer connections formed by network routing algorithms. It proposes AARP architecture that contains application layer resources, AARP server to coordinate set up, modification and release of logical connections and yellow page directory server to track resource utilization in application layer.

In this paper, we propose a distributed multi-path routing algorithm based on reliability of the source–terminal paths. Initially, each node in a network graph gathers connectivity information from its adjacent nodes and forms an adjacency matrix of the graph. It then prepares all possible paths toward each node and calculates the reliability of the paths selected based on number of paths and hop counts (or any other cost parameter may be used). Now two best possible paths based on reliability are selected and the corresponding adjacent nodes are included in its routing table for routing information. Since the routing decision is made based on source–terminal paths, the proposed routing technique is free from loops and the count-to-infinity problem, thus it is better than any distributed routing protocol. The rest of the paper is organized in the following manner. In Section 2 the network model and estimation of reliability is given in detail. Section 3 depicts the explanation of the proposed technique for path selection with an illustrative example. In Section 4 the technique for multi-path routing with numerical results is presented and finally, the conclusion is given in Section 5.