Back-pressure based routing protocol

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Abstract

Shortest path routing schemes can lead to hot-spots or bottlenecks on some links, in spite of resources remaining under-utilized elsewhere in the network. Hence, adapting the routing to network conditions through Traffic Engineering (TE) is essential for the efficient use of network resources. For this purpose, Internet Service Providers (ISPs) currently deploy TE over routing protocols, using techniques such as Multi-Protocol Label Switching (MPLS). But, these TE techniques generate additional protocol overhead and have high reaction time to changes in the network. Integrating TE capabilities with the routing scheme can bring about faster reaction to traffic variations as well as better utilization of resources. Our project involves developing and testing a distributed routing protocol capable of handling traffic variations in the network. The proposed protocol, based on the idea of backpressure routing, will route traffic along the best path determined by combining the information on path length as well as the congestion in the network.

Problem Statement

Routing decisions of shortest path routing protocols are solely based on pre-assigned costs in the network and are agnostic to the real traffic. This can lead to congestion in some parts of the network and under-utilization elsewhere. We can achieve greater responsiveness to traffic variations and freedom from hot-spots by relying on protocols that combine distance information with knowledge about congestion in the network.

Backpressure routing protocol [1] is based on the idea that queue lengths provide direct indication of congestion in the network. Each node in the network decides the next hop for incoming traffic by comparing its queue length with that of its neighbors. The largest difference in queue length, i.e. the largest gradient, will occur along the best path towards destination. Thus, each node forwards traffic based on queue length information received from its immediate neighbors.

Backpressure routing scheme is throughput optimal,i.e., if the incoming traffic is within the capacity region of the network, the protocol will route it successfully. In spite of its throughput efficiency, backpressure protocol is not widely used in practice due to several limitations. First, the protocol does not consider path lengths. Forwarding decisions are solely based on local congestion information. This causes routing loops and delays in the network. Second, each node has to maintain separate queues for every destination in the network. This is impractical for conventional switches with limited buffer space. However, the protocol does provide interesting features such as throughput-optimal routing and congestion-awareness.

Recently, several ideas have been proposed [2, 3] that combine the notion of shortest path routing with backpressure protocol. This opens an exciting arena for congestion-aware shortest path routing. In particular, one of the variants [2] also obviates the need for multiple queues per node. But the efficiency of the algorithm is not flushed out completely by the limited simulations performed on it. The theoretical foundation also needs further work to be developed into a fully-functional distributed protocol. Our project aims at extending this work to develop a throughput-optimal congestion-aware distributed routing scheme. We will design and deploy an optimized variant of the basic backpressure protocol in a testbed and analyze its performance with realistic traffic patterns.

Related work

Tassiulas and Ephremides discovered that queue length is an indicator of congestion in the network while exploring max-weight scheduling in wireless networks and leveraged this information for maximizing throughput in wireless environment [1]. The original backpressure algorithm was the extension of max-weight scheduling algorithm in multi-hop wireless networks. This algorithm was independently discovered as a solution to multi-commodity flow problem by Leighton et. al. [4]. McKeown et al. [5] extended this idea to input-queued switches and introduced the notion of throughput optimal routing in wired networks. Although the idea of backpressure routing had been introduced more than two decades ago, it is not widely used in practice due to poor delay performance caused by routing loops. In spite of its shortcomings, we propose to explore this direction further since backpressure is the only proven technique that can achieve throughput optimal routing in a distributed manner with no a priori knowledge about the traffic patterns. While protocols such as modified OSPF [6], DEFT [7], PEFT [8] etc. combine traffic engineering with routing, they involve centralized computation which prevents a completely distributed deployment. On the other hand, backpressure algorithm can be implemented as a totally decentralized protocol.

Several modifications have been introduced to improve the performance of the traditional backpressure algorithm. Backpressure Control Protocol [9] used in sensor networks replaces FIFO service with LIFO service to improve delay performance. The importance of using shortest paths with backpressure to reduce delay was first put forward by Neely et al. [10]. [11] also notes that lack of a metric that indicates closeness to the destination, is a cause for poor delay performance of opportunistic protocols such as backpressure. Multiple variations of backpressure protocol that rely on the notion of shortest paths to reduce delays have been proposed later. Ying et al. [3] uses the shortest path information by maintaining additional queues at each node corresponding to hop-counts. Packet-by-packet adaptive routing [2] also combines shortest path and backpressure routing to achieve high performance. It provides an elegant solution for separating routing and scheduling by introducing the notion of shadow packets. Separating the backpressure computation from the real packet routing using shadow packets was first proposed in [12] and [13]. The notion of backpressure has also been explicitly combined with shortest path routing in [14].

As an optimization, we intend to use the idea of proportional sharing of links introduced by Walton [15] to speed up the convergence of backpressure routing.

Approach and expected milestones

Brainstorm and identify suitable optimizations to reduce communication overhead and convergence time. Build a custom simulator for testing various optimizations of the back-pressure protocol and identify desirable features for the distributed protocol.	*Mar 31*
Optimizations adopted for the protocol and performance evaluation on the simulator for midterm report	*Apr 6*
Run the protocol as an overlay between 2-3 machines and verify the protocol details	*Apr 10*
Implement and deploy optimized version as an overlay network on a testbed (OCEAN or Emulab)	*Apr 20*
Collect realistic network traffic data for experiments and test the new protocol	*Apr 25*
Analyze performance in terms of following metrics: Convergence time of the protocol, routing delay and communication overhead	*Apr 30*
Final report	*May 11*

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