A New Distributed and Adaptive Approach to Routing and Load Balancing in Dynamic Communication Networks

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Extended Abstract

This paper describes a new family of distributed routing algorithms for achieving load balancing in dynamic communication networks. Routing indeed has a dramatic impact on the overall performance of communication networks; it directly influences the throughput and the average delays of information messages.

Routing has traditionally been carried out in a more or less centralised way that scales badly to the communication network continuous growth (see the Internet for example). Furthermore, network usage is also evolving: many devices become mobile and some sort of guaranteed Quality of Service (QoS) is now often required. Hence, communication networks are everyday more dynamic and the chosen routes need to be rapidly readapted to the changing load and topology.

This paper examines the potential of a new family of distributed methods for packet-switched networks in which the information is split into packets and transits into the network along potentially different routes. The routing tables are here regularly updated without central control nor complete knowledge of the network topology. An estimate of the current load is measured from statistics gathered from *routing packets* sent in the network by the routers. These routing packets mix with the regular information packets and keep track of the delays encountered during their journey. The basic idea of this new approach is inspired by the observation of a dynamic structuration of some insect societies; in particular, some entomologists have shown that the shortest path between an ant nest and a food source can emerge from the local interactions between non directly communicating individuals [1].

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From Classical Routing Algorithms to a New Family

Historically, the routing algorithms used in communication networks have evolved from static routing in which "good routes" are computed off-line to more dynamic routing in which the routes are computed online to take the node congestion level into account. Classical routing protocols were successively based, for example, on *Static Routing*, *Adaptive Distance Vector Routing* in which the routing table are regularly updated and *Adaptive Link State Routing* which also maintains a map of the network topology and delay pattern on each nodes. This evolution is associated with an increase in the number of routing packets transiting on the network. However, these routing algorithms react rather slowly to changes in the network load or topology and they are prone to oscillations. In addition these algorithms face a major increase in the required memory when several metrics are taken into account for guaranteeing different qualities of services.

The new family of algorithms presented here is a natural extension to these classical algorithms. It combines the ideas of online asynchronous distance vector routing with adaptive link state routing. As in online asynchronous distance vector routing ([3]), the delays are directly measured from the network traffic instead of being estimated by each node according to on-site data (e.g. from the waiting buffers length). Each router generates routing agents, usually implemented as routing packets that share the same transmission line with the data packets. They measure traffic delays and allow an online and asynchronous update of the routing tables. From link state routing, these new methods retain the idea of keeping topological information about the network. But instead of having an identical map of the network duplicated on the nodes, the topological information is here distributed on the routing agents themselves: every agent memorises the sequence of switching nodes visited during its journey.

At regular interval, every network node emits routing packets with a randomly selected destination. All packets select their next hop, following a random scheme, proportionally to the information stored in the routing table, i.e. the probabilities of selecting a link for a given destination. To favour the exploration of new routes, random hop is times to times selected with a tiny probability.

Comparison of Different Routing Agents

We consider here two types of routing agents depending on when the distance vector update occurs. This can be performed by the agents going to their destination (*forward routing*) or when they retrace their way back to their source (*backward routing*).

Backward Routing

We will first present two versions of backward routing: an original approach derived from the online asynchronous distance vector routing algorithm ([6]) and the *AntNet system* that has been shown to outperform many aspects of the OSPF routing algorithm on a packet-switching network simulator by Di Caro and Dorigo ([5] and [4]). We propose an immediate improvement based on Bellman's principle that increases the collaboration between agents ([2]).

Backward routing requires the agent to reach its destination before any update to begin. This intrinsically slow round-trip reaction to changes in the network might induce oscillations. Forward routing offers an alternative by removing the need of round-trips.

Forward Routing

Forward routing was first introduced by Schoonderwoerd et al. ([7]) in the case of symmetric networks (e.g. identical costs associated with both link directions). This paper extends this approach to asymmetric networks (e.g. packet-switched networks in which asymmetric delays occur due to different queue lengths). If the network is symmetric, the cost measured by forward agents on their path from the source to the current node can directly be used to update the estimation of the destination toward the source from the current node. For asymmetric network, this cannot be done anymore and this paper introduces a new method to work around this problem.

Experimental Results

All these routing algorithms are experimentally compared in terms of the average packet delay, the number of waiting packets and the throughput in discrete event network simulations. On static networks, this comparison shows the positive impact of the proposed Bellman's improvement. The robustness to link failures and to sudden changes in traffic loads are then studied with dynamic networks. The load balancing performances are also discussed under several traffic patterns. Asymmetric forward routing outperforms the other considered routing algorithms on all these aspects.

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