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On a bi-dimensional dynamic alternative routing method

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Abstract

The analysis of a bi-dimensional dynamic routing model for alternative routing telecommunication networks led to the identification of an instability problem in the synchronous path selection associated with the complex interdependencies among the coefficients of the objective functions and the computed paths for every node pair. In this paper an analytical model enabling to make explicit this problem and evaluate its effects in terms of two global network criteria, is presented. Also a heuristic procedure dedicated to overcome this instability problem and select "good" compromise solutions in terms of network performance is developed. Finally the performance of the proposed routing method using the heuristic is compared by recurring to discrete-event simulation with a reference dynamic routing method (Real Time Network Routing) for some test networks.

Keywords: Bi-criteria analysis; Routing; Heuristics; Telecommunications

1. Introduction and background

Routing is a key element of any telecommunications network functional structure and has a decisive impact on network performance and cost. A routing method is primarily concerned with the determination and selection of a path or set of paths between every pair of nodes of the network representation, seeking to optimise certain objective(s) and satisfy certain constraints of a technical nature. In the formulation of the various routing problems in telecommunication networks these may be modelled through *teletraffic networks* the description of which involves the following elements: a graph (V, L) defining the network

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topology where the nodes $v \in V$ may represent switches, exchanges (groups of switches with known architecture) servers or routers and the arcs (or links) $l \in L$ represent transmission facilities; the capacities of the arcs expressed in terms of bandwidth or equivalent number of transmission channels (usually based on multiples of 64 kb/s); the node-to-node traffic flows which in general may be modelled as stochastic marked point processes (enabling to represent the instants of call arrivals, their duration, bandwidth requirements or other technical requirements); the routing principle specified in terms of the essential features of the routing function (in the network), e.g. whether it is static or dynamic and the number of paths which may be attempted by a call of any given traffic flow or the maximum number of links per path. A routing method can be defined as a particular specification of a certain routing principle, including as key element the algorithm or set of rules which enables to perform the path computation and path selection for every traffic flow having in mind the objective(s) and requirements of the underlying routing principle.

The evolution of multiservice telecommunications network functionalities leads to the necessity of dealing with multiple, fine grain and heterogeneous quality of service requirements which will have to be reflected in some manner in the routing problem formulation. When applied to routing methods this concern led to a new routing concept designated as QoS (Quality of Service) routing which involves the selection of a chain of network resources satisfying certain QoS requirements and seeking simultaneously to optimise the route associated metric(s) (or a sole function of different metrics) such as cost, delay, number of hops or blocking probability. This trend implies considering explicitly distinct metrics in routing algorithms such as in references [22,23] or [20]. In this context the path selection problem was normally formulated as a shortest path problem with a single objective function, either a single metric or encompassing different metrics. QoS requirements were then incorporated into these models by means of additional constraints and the path selection problem (or routing problem in a strict sense) was solved by resorting to different types of heuristics usually based on Dijkstra or Bellman-Ford shortest path algorithms.

Therefore there are potential advantages in modelling the routing problem of this type as a multiple objective problem. Multiple objective routing models enable to grasp the trade-offs among distinct QoS requirements by enabling to represent explicitly, as objective functions, the relevant metrics for each traffic flow and treating in a consistent manner the comparison among different routing alternatives.

On the other hand, the utilisation of dynamic routing (i.e. a routing principle involving the calculation of time-variant paths or path sets between every pair of nodes as a function of relevant measurable network functioning characteristics) in various types of networks is well known to have a quite significant impact on network performance and cost, namely considering time-variant traffic patterns, overload and failure conditions (see for example [12] and [4]).

In the case of circuit-switched alternative routing networks any call of traffic flow f from node v_i to node v_t may attempt paths $r^1(f)$, $r^2(f), \ldots, r^M(f)$ in this order; the first path (or route) with at least one free channel (channel is here defined as the amount of arc capacity required to carry a call of flow f) in every of its arcs and satisfying other possible requirements of the routing method will be the one to be used by the call; if none of those paths satisfies these conditions the call is lost, the associated probability being designated as marginal blocking probability (or call congestion) for traffic flow f. In alternative dynamic routing methods the traffic flexible carrying capacity of alternative routing is associated with the adaptive nature of dynamic routing by enabling the network routing to react in an effective manner (with respect to pre-defined criteria) to dynamic changes in traffic intensities, namely in overload conditions, and to failure states in the links and/or nodes of the network. These methods are the most efficient (albeit complex) type of routing methods conceivable for these networks.

In a previous paper [9] the authors presented the essential features of a 'multiple objective dynamic alternative routing method' (MODR in short) of