**Équipe Network Research Group**
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**Thesis subject**
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# Internet Service Provider Networks & Multi-Path Routing

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## Context

ISP networks must guarantee a given degree of connectivity to their customers. This induces specific structural patterns in the underlying graph (in particular the assurance of minimum redundancy via k-connexity properties at the link level and / or router). Another problem inherent to ISP networks is the optimization of their resources. This objective can be achieved and implemented at the routing level. Multi-path routing is one of the options that allows for load balancing in order to limit congestions. Several mechanisms for load balancing have already been employed in core IP networks. Studies and measurement campaigns such as [1] have put in evidence the use of ECMP [2] which allows one to distribute the load on multiple routes of equal cost. Nevertheless this type of mechanism does not offer an optimal path diversity and may be quite limited depending on the IGP weights allocation.

Modeling and mapping [3] the structure of the Internet are important issues to understand its behavior and characteristics in a global sight. The Internet topology is usually represented by a graph of routers [4] (or sometimes a graph of autonomous systems [5]), the edges of this graph possibly being valued by one weight or more. The interesting properties related to IP routing concern the degree of nodes [6], the diversity of paths, average distance, the logical weight attributed to the links, etc. The evaluation of new routing protocols is generally based on simulations or experimental deployments : the relevance of the results obtained through this type of experimentations depends on the quality of the models used, and among them, the quality of models of Internet topology. In this work, once some graph properties will be extracted from a subset of real networks, we wish, among other objectives, reverse the problematic : how to adapt the graph and its valuation to enable efficient multipath routing protocols ?

## Subject

In addition to a preliminary study on the understanding of the Internet topology and its structural characteristics, the objective of this thesis is to study the relationships linking the graph structure of IP networks and the opportunity to establish an efficient multi-path routing protocol. Examining the multipath routing algorithms and protocols in the literature [7, 8, 9], the first step is to define what an efficient multipath routing is. Several indicators and metrics can be relevant depending on the purpose : the amount of routes that are discovered, their lengths, their coverage (are they totally or partially disjoint, what is the resulting maximum flow ?), etc.. The issue of valuation is then prevalent : is it easier to valuate the links to efficiently enable multi-path routing, or to get rid of this logical overlay for only relying on the physical structure ? It is also interesting to consider the problematic of load balancing : it is not necessary that all routes are simultaneously used by the sharing mechanism. Can we link a given number of indicators associated to the topology (degree of nodes, distribution of these degrees, k-connectivity, etc.) to those that characterize the efficiency of multipath routing ? Is it possible to state, a priori, and knowing the characteristics of a network topology, what multi-path routing algorithm will be most efficient ? Reciprocally, can we, given a specific routing algorithm, infer models of graph that are adapted and favor its effectiveness ? Does there exist structural patterns that affect the establishment of multiple routes or, conversely, does there exist any patterns that favor it ?

## Références


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