Proposal for a PhD thesis - MAPi doctoral program

Title:
Enhancing Internet Routing Optimization Techniques using Evolutionary Computation

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Background:
In the last few years, several new types of applications have been integrated into IP based networks, fostering the development of novel network solutions that aim to provide end-users with Quality of Service (QoS) support. To accomplish this aim, distinct QoS aware architectures and specific traffic control mechanisms were proposed by the networking research community to provide distinct service levels to networked applications. Independently of the set of mechanisms that might be in place in any QoS capable infrastructure, there are some components which have a crucial importance irrespective of the particular solutions adopted. One of such components has the ability to control the data path followed by packets traversing a given network domain.
In this regard, intra-domain routing protocols such as Open Shortest Path First (OSPF) are an attractive alternative, where the administrator assigns weights to each link in the network and these are the only parameters that control the routing behaviour. These protocols are simpler to deploy when compared to more complex alternatives such as MPLS. Since, in these cases, the weight setting process is the way administrators can affect the network behaviour, this choice is of crucial importance and may have a major impact in the network performance. Nevertheless, in practice, simple rules of thumb are typically used in this task, leading to sub-optimal network resource utilization. Therefore, the use of optimization methods to set the parameters of these routing protocols (e.g. OSPF weights) makes an interesting approach to traffic engineering. In this case, it is assumed that the network administrator has access to the predicted demands between each pair of routers along with other possible QoS requirements (e.g imposed by service level agreements). However, this optimization task is quite complex, as it has been shown that the underlying problem is NP-hard, even when the objective function is simply to minimize network congestion. In this context, methods from the Evolutionary Computation field are a promising solution that has been successfully applied in other domains, given their robustness, reliability and generality.

Objectives:
In this work, the major aim will be to address traffic engineering, using intra-domain routing protocols and considering a multi-constrained optimization scenarios.

Therefore, a number of possibly conflicting objectives will be addressed including, for instance, several QoS related measures of the network behaviour (e.g. link congestion, end-to-end delays). Moreover, the increasing need to improve the resilience levels and adaptive capabilities of the network infrastructures also pose new challenges to traditional approaches used in the context of traffic engineering.

In detail, this thesis proposal has the following scientific/ technological objectives:

- To study several optimization techniques in order to approach the previously defined traffic engineering task, namely meta-heuristic methods from the field of Evolutionary Computation that may be able to provide a good solutions in useful time. This also includes the development and fully evaluation of multi-objective optimization methods that can approach the multi-constrained optimization functions for link-state routing (e.g. OSPF) optimization.

- To develop enhanced optimization techniques that can handle important issues such as: *i)* changes in traffic demands or other QoS requirements; *ii)* assuming different demands over distinct time periods; *iii)* link failures in the network; *iv)* provide useful feedback regarding possible improvements to the used network infrastructure. For each one of the previous topics, a sensibility analysis will be crucial to assess the quality and resilience levels of the corresponding optimization solutions.

- To develop computational tools that can be used in real-world scenarios, namely by network administrators. These tools should be easy to use, providing a simple interface and hiding the complexity usually associated with the proposed optimization methods. Based on simple and intuitive inputs, such tools should provide enhanced network routing configurations. The tools should also provide qualitative and quantitative metrics regarding the network performance being also able to provide suggestions to improve the network performance (e.g. by proposing changes in the topology, increasing link capacities, etc.).

References:

1. B. Fortz and M. Thorup. Internet Traffic Engineering by Optimizing OSPF Weights. In Proceedings of IEEE INFOCOM, pages 519-528, 2000.
2. Z. Michalewicz. Genetic Algorithms + Data Structures = Evolution Programs. Springer-Verlag, USA, third edition, 1996.
3. R. K. Ahuja, T. L. Magnati, and J. B. Orlin. Network Flows. Prentice Hall, 1993.
4. Pedro Sousa, Miguel Rocha, Miguel Rio, Paulo Cortez, Efficient OSPF Weight Allocation for Intra-domain QoS Optimization, IPOM 2006 - 6th IEEE International Workshop on IP Operations and Management. Dublin, Ireland, LNCS 4268, pp. 37-48, Springer-Verlag, October 2006.
5. Pedro Sousa, Miguel Rocha, Miguel Rio, Paulo Cortez, Automatic Provisioning of QoS Aware OSPF configurations, Journal of Networks (JNW), 2(2):1-10 , Academy Publisher, April 2007.
6. Miguel Rocha, Pedro Sousa, Paulo Cortez, Miguel Rio, Quality of Service Constrained Routing Optimization using Evolutionary Computation, in Applied Soft Computing Journal, Elsevier. (accepted paper)