Outsourcing Routing using SDN: The Case for a Multi-Domain Routing Operating System

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The art of routing encompasses many more skills than the mere knowledge of how a routing protocol works. This includes the optimization of traffic flows via traffic engineering, correctly mapping Service Level Agreements (SLAs) to policies and then to low-level distributed configuration, coping with errors and scalability issues, while at the same time properly securing the network. Each of these oftentimes competing goals requires tuning several knobs in the routing protocol. Therefore, optimizing how packets are routed within an ISP to satisfy numerous operational and economic objectives is a very challenging problem. Although a number of advanced traffic engineering techniques have been proposed, for example based on integer-programming and multi-commodity-flow optimization, network domains are usually run based on simple best practices that do not necessarily meet all the specific needs of an ISP. In addition, the router configuration code an ISP needs to develop, debug, and update is extensive, while the manual configuration of routers requires many work-hours and is an error-prone process.

In this work, we propose the unconventional idea of *outsourcing* the routing control logic of an ISP to an external trusted provider, i.e., the service contractor[1]. Outsourcing enables the logical centralization of the routing control plane beyond AS boundaries. It is supported by a number of technical and financial incentives, which form the grounds of a techno-economic framework for improving inter-domain routing. We have recently presented thoroughly the incentives that support our model in [5]. In a nutshell, the outsourcing service contractor specializes in routing management and can relieve the ASes of the burden of maintaining expensive, highly-trained staff who manage the cumbersome routing complexity. With its extensive knowledge on routing the contractor can tailor routing configuration to the exact requirements of a client ISP. In addition, each ISP can preserve its policy-shaping capability, privacy and business identity.

In this context, Software Defined Networking (SDN) is the key to a successful outsourcing model. SDN enables a Network Operating System (NOS) [4] which interacts with packet forwarding elements. Control applications, including routing algorithms, can be deployed on top of the NOS and run as software modules. One of the most important SDN principles we can exploit to enhance routing is the separation of routing from forwarding elements, which allows to logically centralize the routing control plane. The benefits of these concepts have been shown in previous research, e.g., in [3], and *intra-AS* routing platforms based on these principles such as RCP [2] or RouteFlow [7] have been

[1] Lakshminarayanan *et al.* [6] first introduce Routing-as-a-Service in the context of tussle resolution between ISPs and customers: route computation is outsourced to external mediators who calculate end-to-end, cross-domain paths through virtual link stitching. Instead, we propose outsourcing the entire per-AS routing logic and combining the inputs from multiple ASes for improving inter-domain routing.

proposed. A centralized routing control plane *within* an AS is a feasible concept and is capable of simplifying routing management.

The SDN-based model we propose [5] targets the *inter-AS* level, enabling to reap the benefits of routing centralization *beyond* AS boundaries. Since a contractor manages routing for multiple ASes, it can take advantage of this multi-AS level of logical centralization and aggregation in order to improve inter-domain routing. The bird's eye view which each contractor has over its client's domains establishes the logically centralized *multi-AS routing plane* as the natural place to take efficient routing decisions, detect policy conflicts, troubleshoot inter-domain routing problems, and evolve protocols like BGP in a legacy-compatible fashion. As a consequence, the model benefits inter-domain routing, while the need to change the core of BGP is obliterated.

In our on-going work we design and have started implementing a multi-AS network operating system for inter-AS routing. There are several challenges involved in building such a system. First and foremost, resilience is a crucial factor for a real-world deployment and needs to be ensured even under the most adverse conditions. There are two sides to resilience. For one, and this has been shown in earlier work, resilience requires a distributed design of the logically centralized controller. Further on, in the design we propose, part of the routing logic needs to be located at the the contractor's premises to enable efficient routing decisions. In order to guarantee availability we need to think about fall-back routing mechanisms in case the connectivity to the contractor is severed. Building on a resilient platform, we intend to leverage the potential of improving routing efficiency, both in terms of path lengths and in terms of convergence times. Another interesting aspect is that the contractor should be able to guarantee the privacy of its clients' business policies. This has to be considered when optimizing routing on a global scale, and when resolving policy conflicts. Further goals include scalability, security, evolvability and extensibility. The proposed research-track talk will outline our key idea of outsourcing routing and our on-going research on the design and implementation of a multi-domain routing OS.

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