The primary protocol for interdomain routing in today's global internet is BGP, which mainly provides inflexible, course-grained routing based only on the destination IP address. More flexible interdomain routing, i.e. based on the full TCP/IP 5-tuple, has a range of potentially useful applications, including DDOS mitigation and inbound traffic engineering. I recently worked with others\(^1\) to develop FRIEND, a two-layer model to achieve flexible interdomain routing. Under the FRIEND model, an autonomous system (AS) providing such a service (the "provider") allows other ASes ("clients") to specify routing actions at the provider based on flexible matching conditions. In this way, a client AS using the flexible interdomain routing service can offload access and traffic control to provider ASes, leading to a simpler client network configuration while giving the provider ASes additional business opportunities.

In the FRIEND control plane layer, customers and providers communicate to set up desired fine-grained routes for traffic that transits the provider on its way to the customer. An example would be a customer requesting that all inbound HTTP traffic be forwarded from the provider along one link, and non-HTTP traffic be forwarded along another link. The signaling plane layer augments BGP to ensure that each AS in the system still has an accurate view of its available routes, ensuring stability and scalability.

Proposals

While the FRIEND model that we developed is a good starting point for thinking about how to achieve flexible interdomain routing, it has a number of shortcomings. I propose to extend on the FRIEND model in some of the following ways:

1. Unified Control Plane

Other systems prior to FRIEND have been proposed to achieve greater flexibility in interdomain routing. Examples include SDX\(^2\), MIRO\(^3\), and ARROW\(^4\). A generic unified

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\(^1\) Qiao Xiang, Jensen Zhang, Danny Lachos, Daniel Ernst, Yeon-Sup Lim, Franck Le, Richard Yang. *Toward Flexible Interdomain Routing as a Service*. Submitted to SIGCOMM ’19.


model for flexible interdomain routing would be a powerful abstraction that could cleanly enable many use cases in the global internet. This unified model should be a superset of these other systems. I aim to show how SDX, MIRO, and ARROW are all special cases of the FRIEND model, and consequently how one can craft rules in FRIEND to achieve the same results as SDX, MIRO, and ARROW. If it turns out that this is not possible, I will extend FRIEND so that it is a truly generic, unified control plane.

2. Compilation Within an AS

Another feature lacking from the original FRIEND paper is an explanation of how many different policies from different ASes as part of the virtual switch abstraction could be compiled into lower-level forwarding rules for physical switches inside a single AS. In particular, detailing the compilation process is important because issues of efficiency and policy-conflict may arise. SDX provides a solid model for compilation, and I hope to create something similar for FRIEND.

3. Extending the Signaling Layer

The signaling layer of the FRIEND model is important because it ensures that implementing FRIEND does not affect reachability within the system, or stability and scalability. While the current signaling layer model is a strong start, it places large constraints on the way the system can be used (i.e. it limits the potential policies in a way that is probably not necessary). Moreover, some of the conditions imposed by the signaling layer may not be verifiable. Meanwhile, a thorough analysis of the scalability of the system as a whole – with global propagation of control plane messages – has not yet been performed. More work in this area could alleviate some of these problems, increasing the usefulness of the FRIEND model without compromising reachability, stability, or scalability.

4. Better Understanding the Potential Applications

The original FRIEND paper details how the model could be useful in limiting the impact of DDOS attacks, and begins to show how it could be useful for inbound traffic engineering. There are surely many more – and more detailed – applications for the powerful capability that FRIEND exposes. A more detailed analysis in conjunction with talking to industry professionals would lead to a better understanding of key applications.

DELIVERABLES

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I presented above four concrete areas of extension for the FRIEND model. Tackling all of them would be a very ambitious goal that may not be feasible in a single semester. However, I will attempt to solve several of these issues, and present my results in a written report.