Path Aware Networking RG
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Open Questions in Path Aware Networking
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Abstract

This document poses open questions in path-aware networking, as a background for framing discussions in the Path Aware Networking proposed Research Group (PANRG). These are split into making properties of Internet paths available to endpoints, and allowing endpoints to select paths through the Internet for their traffic.

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1. Introduction to Path-Aware Networking

In the current Internet architecture, the network layer provides an unverifiable, best-effort service: an application can assume that a packet with a given destination address will eventually be forwarded toward that destination, but little else. A transport layer protocol such as TCP can provide reliability over this best-effort service, and a protocol above the network layer such as IPsec AH [RFC4302] or TLS [RFC5246] can authenticate the remote endpoint. However, no explicit information about the path is available, and assumptions about that path sometimes do not hold, sometimes with serious impacts on the application, as in the case with BGP hijacking attacks.

By contrast, in a path-aware networking architecture, endpoints have the ability to select or influence the path through the network used by any given packet, and the network layer explicitly exposes information about the path or paths available between two endpoints to those endpoints so that they can make this selection. Path control at the packet level enables new transport protocols that can leverage multipath connectivity even over a single interface.

2. Questions

Realizing path-aware networking requires answers to a set of open research questions. This document poses these questions, as a starting point for discussions about how to realize path awareness in the Internet, and to direct future research efforts within the Path Aware Networking Research Group.

2.1. A Vocabulary of Path Properties

In order for information about paths to be exposed to the endpoints, and for those endpoints to be able to use that information, it is necessary to define a common vocabulary for path properties. The

elements of this vocabulary could include relatively static properties, such as the presence of a given node on the path; as well as relatively dynamic properties, such as the current values of metrics such as loss and latency.

This vocabulary must be defined carefully, as its design will have impacts on the expressiveness of a given path-aware internetworking architecture. This expressiveness also exhibits tradeoffs. For example, a system that exposes node-level information for the topology through each network would maximize information about the individual components of the path at the endpoints at the expense of making internal network topology universally public, which may be in conflict with the business goals of each network's operator.

The first question is therefore: how are path properties defined and represented?

2.2. Discovery, Distribution, and Trustworthiness of Path Properties

Once endpoints and networks have a shared vocabulary for expressing path properties, the network must have some method for distributing those path properties to the endpoint. Regardless of how path property information is distributed to the endpoints, the endpoints require a method to authenticate the properties - to determine that they originated from and pertain to the path that they purport to. The end goal of authentication is not necessarily to establish that a given property is actually bound to a given path, but to ensure that the information is trustworthy, that actions taken based on it will have the predicted result.

Choices in an distribution and authentication methods will have impacts on the scalability of a path-aware architecture. Possible dimensions in the space of distribution methods include in-band versus out-of-band, push versus pull versus publish-subscribe, and so on. There are temporal issues with path property dissemination as well, especially with dynamic properties, since the measurement or elicitation of dynamic properties may be outdated by the time that information is available at the endpoints, and interactions between the measurement and dissemination delay may exhibit pathological behavior for unlucky points in the parameter space.

The second question: how do endpoints get access to trustworthy path properties?

2.3. Supporting Path Selection

Access to trustworthy path properties is only half of the challenge in establishing a path-aware architecture. Endpoints must be able to use this information in order to select paths for traffic they send. As with path property distribution, choices made in path selection methods will also have an impact on the scalability and expressiveness of a path-aware architecture, and dimensions included in-band versus out-of-band, as well. Paths may also be selected on multiple levels of granularity - per packet, per flow, per aggregate - and this choice also has impacts on the scalabilty/expressiveness tradeoff.

The third question: how can endpoints select paths to use for traffic in a way that can be trusted by the network?

2.4. Interfaces for Path Awareness

In order for applications to make effective use of a path-aware networking architecture, the interfaces presented by the network and transport layers must also expose path properties to the application in a useful way, and provide a useful selection for path selection. Path selection must be possible based not only on the preferences and policies of the application developer, but of end-users as well.

The fourth question: how can interfaces to the transport and application layers support the use of path awareness?

2.5. Operating a Path Aware Network

The network operations model in the current Internet architecture assumes that traffic flows are controlled by the decisions and policies made by network operators, as expressed in interdomain routing protocols. In a path-aware network with effective path selection, however, this assumption no longer holds, as endpoints may react to path properties by selecting alternate paths. Competing control inputs from path-aware endpoints and the interdomain routing control plane may lead to more difficult traffic engineering or nonconvergent routing, especially if the endpoints' and operators' idea of the "best" path for given traffic differs significantly.

The fifth question: how can a path aware network in a path aware internetwork be effectively operated?

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4. Normative References

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