Path Steering in CCNx and NDN

Ilya Moiseenko

Dave Oran

draft-oran-icnrg-pathsteering-00

Outline

- Introduction
- Design
- Packet Encoding
- Security Considerations

I. INTRODUCTION

Problem Statement

- ICN communication is inherently multi-path and potentially multi-destination.

- No mechanism for consumers to direct Interest traffic onto a specific path.

  – Forwarding Strategies in ICN forwarders can spray Interests onto various paths

  – Consumers have a hard time interpreting failures and performance glitches

Motivations for Path Steering

❖ Discover, monitor and troubleshoot multipath network connectivity based on names and name prefixes:

   ❖ Ping

   ❖ Traceroute

❖ Accurately measure a performance of a specific network path.

❖ Control multipath congestion:

   ❖ Count number of available paths

   ❖ Uniquely identify a path

   ❖ Allocate traffic to each path

❖ Traffic Engineering and SDN

   ❖ Externally programmable end-to-end paths for Data Center and Service Provider networks

II. Design

How to label paths?

What is a path label? One or more nexthop IDs
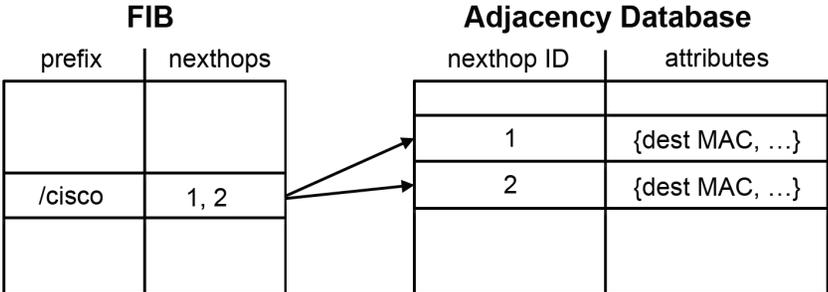
Encoding options:

- Bloom filter

- Pairing function

- Label Stack (similar to MPLS label stack)

- **Fixed size labels – This is what we chose (see later slide)**

FIB

prefix	nexthops
/cisco	1, 2

Adjacency Database

nexthop ID	attributes
1	{dest MAC, …}
2	{dest MAC, …}

Path discovery and steering

Interest$_1$ contains a path label marked as **DiscoveryMode** and is forwarded with LPNM in the FIB
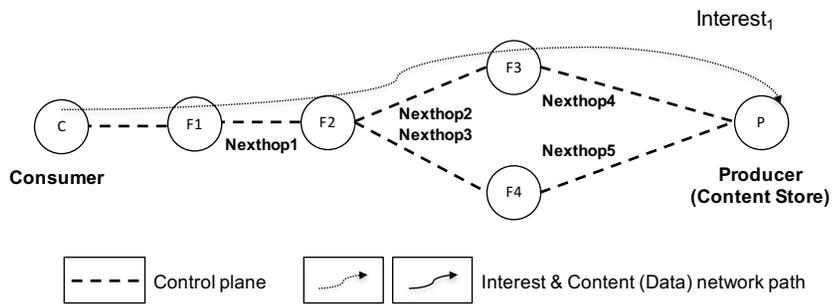
Path discovery and steering

Content$_1$ carries a path label modified on each hop.
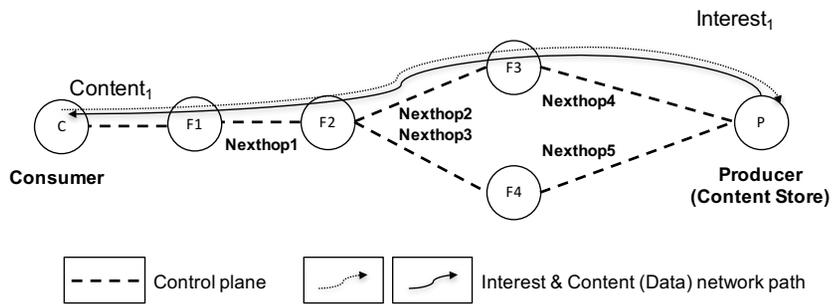
Path discovery and steering

Interest$_2$ has a path label obtained from the earlier returned Data Packet. This a marked as not **DiscoveryMode** and is forwarded with LPNM FIB + nexthop selection.
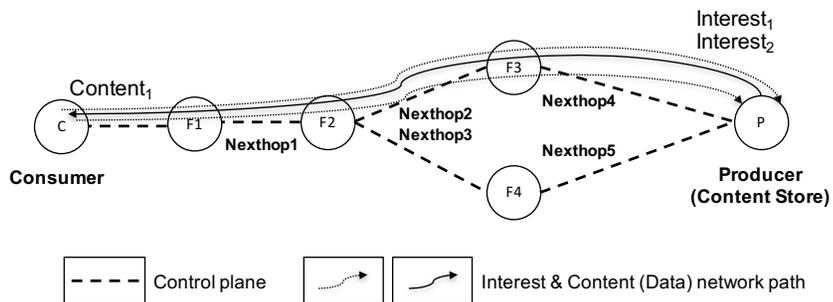
Advantages

- ICN **Ping** application can reliably measure path RTT

- ICN **Traceroute** application can iteratively discover multiple network paths

- Consumer multipath-aware **congestion control** can discover and distribute load across paths

- Consumer can mitigate **content poisoning** attacks

- **Traffic engineering** (TE) and SDN solutions can be built

Route updates

- With path steering, LNPM FIB lookup still used to find the set of nexthops from which the path' nexthop is chosen.
- If nexthop selection fails:
  - Interest-Return (NACK) carrying a new "Invalid path label" error code
  - or silently forward an Interest through any available nexthop
  - Behavior can be controlled through consumer options on Interests:
    - StrictMode
    - FallbackMode
    - DiscoveryMode

Handling Route updates

FIB

prefix	nexthops
/cisco	1, 2

Adjacency Database

nexthop ID	nexthop label	attributes
1	99737	{dest MAC, …}
2	55088	{dest MAC, …}

- New nexthop label(s) assigned every time FIB entry changes
- On reverse path, Data or NACK is dropped
- On forward path, Interest is NACK'ed
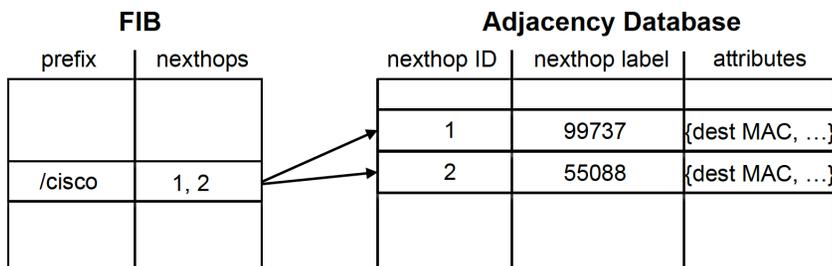
III. Packet Encoding

Additions to CCNx Packet format (RFC8609)

- New Error Code: T_RETURN_INVALID_PATH_LABEL for Interest Return Packet

- New hop-by-hop header TLV: T_PATH_LABEL

- New Registry for Path Label Field TLVs:

  - PATH-LABEL-TYPE

  - PATH-LABEL-BITMAP-TYPE

  - PATH-LABEL-NEXTHOP-LABEL-TYPE

  - PATH-LABEL-HOP-COUNT-TYPE

Path Label Syntax

T_PATH_LABEL		Length + 4	
Flags	Path Label Hop Count	Nexthop Label	
Path Label bitmap (Length octets)			
Nexthop label	Nexthop label	Nexthop label	Nexthop label
12 bits	12 bits	12 bits	12 bits

This design allocates 12 bits (i.e. 4095 as a *generator polynomial*) to each intermediate ICN forwarder. This should match the scalability of today's commercial routers that support up to 4096 physical and logical interfaces and usually do not have more than a few hundred active ones.

IV. Security considerations

Malicious mis-steering

Consumer can use probing with Interests to discover path labels and then steer packets over wrong paths or to wrong destinations to mount a DoS attack.

- 12-bit nexthop label requires only average 2^{12} Interests to discover by malicious consumer

- Mitigation: periodically update nexthop labels to limit the maximum lifetime of paths

- To foil divide-and-conquer, use a void Hop Count field in "Invalid path label" Interest-Return (NACK) message

- Path label can be encrypted hop-by-hop on the reverse path

Cache pollution

Malicious consumer & producer can inject an off-path and potentially bogus object in on-path caches.

- Mitigation: Cache entries must be annotated with the corresponding path label and only used to satisfy Interests with a matching path label.

- Mitigation: Cache entries must not evict entries for the same object with no path label, or a different path label.

Thanks! Questions?