ROAD:
ROUTING BASED ON AUTONOMOUS SYSTEMS AND DOMAIN NAMES FOR NAMED DATA NETWORKING

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Outline

- Introduction
- ROAD Architecture
  - ROAD overview
  - ROAD routing
  - Interest packet format
  - Routing state in router
- Evaluation
- Discussions
Routing in NDN

- A naïve route-by-name approach
  - We can modify OSPF/BGP to advertise every name
  - Too many names
    - **Scalability** is the major issue
Too Many Names: Scalability Problem

- Let’s consider domain names
- The number of domain names is still orders of magnitude higher than that of IP prefixes

About 200 million top level domains

http://www.verisigninc.com

Host Count: 888,239,420 in 2012-01
ROAD Overview

• Objective
  • How to make FIB scalable

• A hierarchical approach
  • Inter-domain
    • If content is outside the current AS
    • Forward interest packets based on ASNs
  • Intra-domain
    • Hash of the domain name of the content is a FIB entry
      • Domain name part indicates the publisher of the content
      • FIB needs to contain only the domain names that belong to its own AS
    • Optionally, we can adopt Virtual Aggregation (ViAggre) to further reduce the number of FIB entries
ROAD Illustration

- Request for content “snu.ac.kr/contentA”

ASN Server

AS 100 (consumer’s AS)

contentA

contentA

AS 300

Find contentA in AS 300

AS 400

ASN=300 (outside)
ASN=100 (inside)

Find contentA in my AS

ASN-based Routing
Inter-domain: How to reach target AS

- Each Router maintains paths to other ASes
  - ASN table is needed
  - Currently, AS count is about 40,000

If ASN=300

<table>
<thead>
<tr>
<th>ASN</th>
<th>face</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>1</td>
</tr>
<tr>
<td>400</td>
<td>1</td>
</tr>
<tr>
<td>500</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ASN</th>
<th>face</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>300</td>
<td>1</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ASN</th>
<th>face</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>400</td>
<td>0</td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>
Intra-domain: How to find content within an AS

- **Virtual Aggregation (ViAggre*) for NDN**
  - Split Routing entries that should be maintained by router
  - Hash of domain name is used for prefix

<table>
<thead>
<tr>
<th>PID</th>
<th>Rprefix</th>
</tr>
</thead>
<tbody>
<tr>
<td>10101010...</td>
<td>11</td>
</tr>
</tbody>
</table>

*H Ballani et al., Making Routers Last Longer with ViAggre, NSDI ’09
Interest packet format

- **Content Name (CNAME)**
  - Variable length
- **AS Number**
  - 32bit
    - Same with current ASN bit
- **R_prefix**
  - 15bit
    - Partition prefix
- **Flag bit**
  - 1bit
    - Check whether packet is encapsulated or not
- **Publisher ID (PID)**
  - 128bit
    - Hash(domain name part of content name)
Routing information in Router

<table>
<thead>
<tr>
<th>ASN Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIB</td>
</tr>
<tr>
<td>(Publisher Info. Base)</td>
</tr>
<tr>
<td>VIB</td>
</tr>
<tr>
<td>(ViAggre Info. Base)</td>
</tr>
<tr>
<td>PIT</td>
</tr>
<tr>
<td>CS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ASN</th>
<th>face</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

AS Count: About 40,000

<table>
<thead>
<tr>
<th>PID (128bit)</th>
<th>( R_{prefix} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>01100101...</td>
<td>5,000 - 40,000</td>
</tr>
<tr>
<td>(Depends on the number of contents in an AS)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>( R_{prefix} )</th>
<th>face</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td></td>
</tr>
<tr>
<td>Number of Routers in AS =&gt; small</td>
<td></td>
</tr>
</tbody>
</table>
Testbeds

- Topology setting

100,000 interests

Interest generator ————> CCNx Router ————> CCNx Router

- On CCNx Platform
- Machine specification
  - Intel Core i3 – 2100 CPU @ 3.10 GHz
  - 3MB level-2 cache
  - 3GB memory
Experiments

- Capacity on one router
- Drop rates at middle router for 4 cases

Interest generator ① Vanilla ② ROAD - local ③ ROAD - other AS ④ ROADv CCNx Router

Vanilla : Original CCNx
Experiments

- Table entries

<table>
<thead>
<tr>
<th></th>
<th>FIB</th>
<th>N/A</th>
<th>ROADv</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vanilla</td>
<td>100,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROAD</td>
<td>100,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ROADv</td>
<td>300</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

- Interest generation
  - 100,000 interest packets
  - Various rates
Results

![Graph showing drop rate vs packets/sec for different conditions.

- Vanilla
- ROAD - local
- ROAD - OtherAS
- ROADv

The graph illustrates the drop rate in packets per second for each condition as the number of packets increases. At lower packet rates, the drop rate is minimal across all conditions. However, as the packet rate increases, the drop rate for ROADv becomes significantly higher compared to the other conditions, indicating potential issues with ROADv under high load conditions.]

AsiaFI NDN Hands-on Workshop 2012
Discussion

• ASN Lookup
  • Why do we take only domain name part
    • Publisher usually does not move across ASes
    • We can figure out AS to which content belongs
  • Local ASN server can be used for finding multiple replica of the content

• ASN-based routing
  • Vs. fine-grained path selection (traffic engineering)
• Split routing state using ViAggre
  • Vs. path stretch

We expect that NDN features (e.g. in-network caching) can alleviate these drawbacks
THANK YOU
Interest Packet for ASN lookup

<table>
<thead>
<tr>
<th>Flag</th>
<th>R_prefix</th>
</tr>
</thead>
<tbody>
<tr>
<td>\n</td>
<td>\n</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Publisher ID (PID)</th>
</tr>
</thead>
<tbody>
<tr>
<td>\n</td>
</tr>
</tbody>
</table>

CNAME = asn-service.ndn

...snu.ac.kr
Design choices for Routing

- **Centralized ways**
  - Each router makes a forwarding decision based on central controllers (e.g. OpenFlow)
    - Cache can be used for popular names (e.g. CONET)

- **Central + decentralized ways**
  - Hierarchical ways
    - Intra-domain routing for decentralized
    - Inter-domain routing for centralized
      - E.g. DNS mapping services

- **Distributed ways**
  - Greedy routings (no need to change global network topology information)
    - E.g. GPS based routing