R-iCDN: an Approach Supporting Flexible Content Routing for ISP-operated CDN

Song Ci

High Performance Network Lab, Institute of Acoustics,
Chinese Academy of Sciences
I. Background

II. Motivation

III. R-iCDN Framework

IV. Performance Evaluation

V. Conclusion
Outline

I. Background

II. Motivation

III. R-iCDN Framework

IV. Performance Evaluation

V. Conclusion
I. Background

• Global Internet traffic is increasing by 29% per year

• More and more ISPs are embracing and building their own CDNs, namely **ISP-operated CDNs (iCDNs)**
  – Verizon, AT&T, ...
I. Background

• iCDN helps ISP to
  – mitigate the pressure of traffic increasing
  – improve user experience
  – monetize online content

• The advantage of iCDN, compared with traditional CDN provider such as Akamai
  – iCDN provider (or ISP) inherently has the detailed knowledge of network information, such as topology and link utilization
Outline

I. Background
II. Motivation
III. R-iCDN Framework
IV. Performance Evaluation
V. Conclusion
Two kinds of traditional iCDN topology

(a) Flat

Geo-distributed
Content
Repositories

Replica Server

... 

(b) Hierarchical

Geo-distributed
Content
Repositories

Regional
Replica Server

Edge Replica Server

... 

• Static content routing - each edge server can **ONLY** connect to one upstream regional server at a time
Deficiency of Traditional I-CDN: An Example Analysis (1)

- A typical site-level topology (backbone network) of nation-scale ISPs in China
  - Hierarchical
  - Multi-homing connectivity
In the physical network, normal node (router) R1 **multi-homing** connects to core node (router) R2 and R3.
Deficiency of Traditional I-CDN: An Example Analysis (2)

- Edge content server S1, Regional content server S2 and S3 are deployed
- Content repository A and B is co-located with S2 and S3 respectively
Deficiency of Traditional I-CDN: An Example Analysis (2)

- Because of static content routing in traditional CDN, S1 is assumed to only connect with S2.
- A detour path is required when S1 retrieves contents from Content Repository B.
Deficiency of Traditional I-CDN: An Example Analysis (2)

- However, an optimized routing path exists!
- A more flexible content routing scheme is required since traditional static content routing cannot fully exploit the underlay network infrastructure.
How does It Work in the Emerging Information-Centric Networks

Shift of Internet Communication Model from Host-centric to Information-centric

Current Internet

ICN

Evolution

In ICN, **shortest-path** content retrieval can be easily achieved since **name-based routing (NBR)** is operated in the network layer where content router has the detail information of physical network, such as network topology and link state.
How does It Work in the Emerging Information-Centric Networks

Shift of Internet Communication Model from Host-centric to Information-centric

Current Internet

- In ICN, shortest-path content retrieval can be easily achieved since name-based routing (NBR) is operated in the network layer where content router has the detail information of physical network, such as network topology and link state.

- May we borrow the idea of NBR to address the problem of inefficient (detouring) content retrieval in current CDN?

ICN

Evolution
Outline

I. Background

II. Motivation

III. R-iCDN Framework

IV. Performance Evaluation

V. Conclusion
R-iCDN Architecture Overview

- R-iCDN, a flexible content routing mechanism of CDN
  - comply with a hierarchical topology, to avoid excessive cache hops
  - each edge server is allowed to multi-homing connect with two or more regional servers to avoid a detour path
  - a centralized content routing engine is needed to decide which server should be forwarded to
Centralized Content Routing Engine

• Main task
  – to generate and populate content routing entries for each replica server in a centralized manner, through collecting both content-level and network-level information
Centralized Content Routing Engine

- **Main task**
  - to generate and populate content routing entries for each replica server in a centralized manner, through collecting both content-level and network-level information

- **Three components**
  - Overlay Topology Setup, Content Prefix Association, Centralized Routing Algorithm
Overlay Topology Setup

• What is overlay topology of R-iCDN
  – The topology between replica servers and content repositories
  – The overlay topology should **fully exploit the underlay network** infrastructure

• Steps
  – Get the site-level topology of underlay network
Overlay Topology Setup

• What is overlay topology of R-iCDN
  – The topology between replica servers and content repositories
  – The overlay topology can fully exploit the underlay network infrastructure

• Steps
  – Get the site-level topology of underlay network
  – map all replica servers into the site-level topology
Overlay Topology Setup

• What is overlay topology of R-iCDN
  – The topology between replica servers and content repositories
  – The overlay topology can **fully exploit the underlay network** infrastructure

• Steps
  – Get the site-level topology of underlay network
  – map all replica servers into the site-level topology
  – Replace a node in the site-level topology with a co-located replica server
Overlay Topology Setup

• What is overlay topology of R-iCDN
  – The topology between replica servers and content repositories
  – The overlay topology can **fully exploit the underlay network** infrastructure

• Steps
  – Get the site-level topology of underlay network
  – map all replica servers into the site-level topology
  – Replace a node in the site-level topology with a co-located replica server
    – Delete the Nodes without co-located any replica servers
Overlay Topology Setup

• What is overlay topology of R-iCDN
  – The topology between replica servers and content repositories
  – The overlay topology can fully exploit the underlay network infrastructure

• Steps
  – Get the site-level topology of underlay network
  – Map all replica servers into the site-level topology
  – Replace a node in the site-level topology with a co-located replica server
  – Delete the Nodes without co-located any replica servers
  – Attach a content repository with a co-located regional server
Content Prefix Association

- Content Prefix Association is to describe what is available at particular replica servers in the graph.
- Only these replica servers (RS) which are co-located with content repositories will be associated with URL prefixes.

Diagram:
- RS 1
- RS 2
- RS 3
- RS 4
- RS 5
- tv.youku.com
- photo.sina.com
- ....
- movie.youku.com
- pps.tv/music
- ....
Centralized Routing Algorithm

- Why is centralized routing algorithm chosen?
  - Simplify the design of routing protocol since no additional protocol messages among replica servers are needed.
  - Be easily integrated with current CDN infrastructure in which the control center, namely mapping system, is also a centralized one.

- Combining the overlay topology with the associated content prefixes, Dijkstra algorithm is used to generate the content routing table for each server.

<table>
<thead>
<tr>
<th>URL Prefix</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>tv.youku.com</td>
<td>IP_addr(RS 3)</td>
</tr>
<tr>
<td>photo.sina.com</td>
<td>IP_addr(RS 3)</td>
</tr>
<tr>
<td>tv.youku.com</td>
<td>IP_addr(RS 4)</td>
</tr>
<tr>
<td>movie.youku.com</td>
<td>IP_addr(RS 4)</td>
</tr>
<tr>
<td>pps.tv/music</td>
<td>IP_addr(RS 4)</td>
</tr>
</tbody>
</table>

Content Routing Table of RS1

<table>
<thead>
<tr>
<th>URL Prefix</th>
<th>Next Hop</th>
</tr>
</thead>
<tbody>
<tr>
<td>tv.youku.com</td>
<td>IP_addr(RS 5)</td>
</tr>
<tr>
<td>photo.sina.com</td>
<td>IP_addr(RS 5)</td>
</tr>
<tr>
<td>tv.youku.com</td>
<td>IP_addr(RS 4)</td>
</tr>
<tr>
<td>movie.youku.com</td>
<td>IP_addr(RS 4)</td>
</tr>
<tr>
<td>pps.tv/music</td>
<td>IP_addr(RS 4)</td>
</tr>
</tbody>
</table>

Content Routing Table of RS2
Outline

I. Background

II. Motivation

III. R-iCDN Framework

IV. Performance Evaluation

V. Conclusion
Experimental Setup

- Evaluated based on a **real nation-scale** site-level network topology, the backbone of China Mobile Internet (CMNET)
  - 31 nodes, including 8 core nodes and 24 normal nodes
  - each normal node multi-homing connects two or more core nodes
- A Java-based simulation environment
  - 5000 contents evenly distributed in 8 content repositories
  - 50000 user requests
  - Zipf popularity distribution ($a=1$)
  - LRU for content replacement
- Compare the performance of R-iCDN with two traditional iCDN architectures, namely **flat-CDN** and **hierarchical-CDN**
Performance Comparison of Network Traffic Volume

- R-iCDN outperforms the other two schemes in all experimental cases.
- R-iCDN reduces the traffic volume by more than 6% on average compared to hierarchical-CDN.
- R-iCDN outperforms flat-CDN by up to 9.8% when total cache budget is 90% and regional/edge size ratio is 10 : 1.
R-iCDN also outperforms the other two schemes in all experimental cases.

R-iCDN slightly reduces the request latency compared to hierarchical-CDN (about 5% when regional/edge size ratio is 1:1)

R-iCDN outperforms flat-CDN by up to 30% when total cache budget is 110% and regional/edge size ratio is 10 : 1
Outline

I. Background

II. Motivation

III. R-iCDN Framework

IV. Performance Evaluation

V. Conclusion
Conclusion

• Borrow the idea of name-based routing in ICN and design a novel ISP-operated CDN architecture.

• A centralized content routing mechanism is proposed to address the issue of topology setup and optimization of CDN overlay network through fully exploiting the underlay network infrastructure.

• A thorough performance evaluation is conducted based on a real nation-scale ISP topology, the backbone network of China Mobile (the largest mobile network operator in the world)
Thank You !