Scalability and Stability of IP and Compact Routing

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Motivation

Active BGP Entries
Motivation

Implications:
- More memory to store FIB
- More frequent routing announcements/withdraws
- Slow routing convergence
- Heavy burden on core routers
Root cause analysis

Multi-homing

- Reliable Internet connection
- Traffic engineering
  - Stub AS can load balance the incoming traffic by splitting its IP prefixes
  - Inject more routes into global routing table
  - Even worse if PI IP addresses are used by stub AS
Root cause analysis

Small world topology

- Cliques
- No remote nodes
  - 3 ~ 4 AS hops on average
- Highly connected hubs
- Power law distribution
Root cause analysis

IP address : Locator + Identifier

• Locator
  ➔ A location, related to topology

• Identifier
  ➔ A name independent of topology
Related work

Locator/Identifier Separation Protocol (LISP)

- Ingress tunnel router (ITR)
- Egress tunnel router (ETR)
- Mapping
- Still based on aggressive routing aggregation
Related work

Aggressive routing aggregation on small world graph is impossible [KcFB07]
Related work

Routing stretch = routing path length/ the shortest path length

Compact routing

- Working principle of compact routing will be introduced later
- Name dependent compact routing
  - Embed topology info into address label
- Name independent compact routing
  - Flat label
  - Name dependent compact routing + dictionary tables
- Some theory results
  - No universal stretch < 3 routing scheme with sub-linear RT size
  - $RT \text{ size } \geq \Omega\left(\frac{1}{n^2}\right)$ for routing scheme with stretch < 5
## Research goals

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<tr>
<th>Routing schemes</th>
<th>Compact routing</th>
<th>Routing aggregation (Traditional IP routing Tunnel-based routing)</th>
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<td>Routing scalability</td>
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<td>Routing stability</td>
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<tr>
<td>Topology</td>
<td>strict hierarchy Internet topology</td>
<td>small world topology</td>
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</table>
Research goals

- Routing scheme
- Address labeling scheme
- Topology
Paper A
A Stochastic Clustering Algorithm for Swarm Compact Routing

Goal:
- Distributed compact routing algorithm
- Large scale Internet inter-domain like topology
- Business model embedded
- Result verification
  - NS-2 based packet level simulator
  - A dedicated tool simulating the steady behavior
Paper A
A Stochastic Clustering Algorithm for Swarm Compact Routing

Diagram:
- : AS
- S: Source AS
- D: Destination AS
- L: Landmark of D
- : Neighbourhood of D
- : Neighbourhood of N
- : Towards Landmark
- : Actual Path

NTNU
Norwegian University of Science and Technology
A Stochastic Clustering Algorithm for Swarm Compact Routing

C : AS
S : Source AS
D : Destination AS
L : Landmark of D

maintains:

- \( p_s \)
- \( p_c \)
- \( \beta \)
- \( t_d \)
- \( L_p \)
- \( L_m \)

\( L_m \) is updated by condition 3.

L selects itself to be the landmark of D based on condition (5).

Each node maintains:
- \( d \)
- \( v_1 \)
- \( R_a \)
Paper A
A Stochastic Clustering Algorithm for Swarm Compact Routing
Local path: source and destination are in the same neighborhood
Only 9.64% paths with stretch $\geq 1.14$
Max stretch is 3

Distant path: source and destination are not in the same neighborhood
9.94% paths with stretch $\geq 1.14$
Paper A
A Stochastic Clustering Algorithm for Swarm Compact Routing

The number of nodes sharing the same landmark is proportional to the landmark's degree.
Shortcut effect

- AS
- Source AS
- Destination AS
- Landmark of D
- Neighbourhood of D
- Neighbourhood of N
- Towards Landmark
- Actual Path
Paper B
A Compact Routing Scheme with Lower Stretch

Status:
• Fixed neighborhood size
• Dense network topology
• Super hubs
Paper B
A Compact Routing Scheme with Lower Stretch

Issues:
• Some nodes do not install routes to their immediate neighbors

Solution:
• Neighbors can communicate directly
Theorem 1. Let $d(u,v)$ denote the length of the shortest path from $u$ to $v$. Then the routing algorithm returns a path of length at most $3d(u,v)$.

Theorem 2. Given the network size $N$, the global routing table grows with a sub-linear factor $\tilde{O}(N^{0.9})$.
Paper B
A Compact Routing Scheme with Lower Stretch

Average stretch against shortest paths

Average stretch per AS hop
Paper B
A Compact Routing Scheme with Lower Stretch

7.5% paths with stretch $\geq 1.14$ for our scheme
9.95% paths with stretch $\geq 1.14$ for Cowen scheme
By calculating the routing stretch for each path
Routing stability

- Node failure
  - Landmark node failure
  - Non-landmark node failure
- Choose failed nodes with different degrees evenly
- Link failure
- Assumption: at any time only one node can fail
Paper C
The Stability of Compact Routing in Dynamic Inter-Domain Networks

Average stretch vs. degree of failed landmark
Paper C
The Stability of Compact Routing in Dynamic Inter-Domain Networks

#New landmarks vs. degree of failed landmarks
10% and 33% respectively for Cowen and TZ
Paper C
The Stability of Compact Routing in Dynamic Inter-Domain Networks

#Nodes changing landmarks vs. degree of failed landmarks
10% and 28% respectively
Paper D
An Impact of Addressing Schemes on Routing Scalability

Goal

• Model the relation between routing scalability, topology and addressing scheme
  → A simple routing model
• Measure address label scalability
• Compare the routing scalability and address label scalability of IP routing, compact routing, flat label routing
  → Different network configurations for IP routing
A simple Internet routing model

\[ S = \{G, I, A, L, T\} \]
\[ T = \{T_1, T_2, \ldots, T_s\} \]
\[ F : A \times A \to L \]
\[ T = \{(a_i, a_j)|F(a_i, a_j) = l, a_i, a_j \in A, l \in L\}. \]

Determines the RT size
Paper D
An Impact of Addressing Schemes on Routing Scalability

A routing model based on flat label

\[ S = \{G, I, I, L, \{T_I\}\} \]

\[ \mathcal{T} = \{T_I\} \]

\[ I = A \]

\[ T = \{(a_i, a_j) | F(a_i, a_j) = l, a_i, a_j \in A, l \in L\} \]

\[ F_I(a_i, a_j) = \begin{cases} a_i, & a_i = a_j \\ \bot, & a_i \neq a_j \end{cases} \]

**Theorem 1:** A scalable routing scheme based on flat address labels \( S = \{G, I, I, L, \{T_I\}\} \) with \( A = I \) and \( \mathcal{T} = \{T_I\} \) does not exist.
Paper D
An Impact of Addressing Schemes on Routing Scalability

For a given routing system

\[ S = \{G, I, A, L, T\} \]

Address label scalability can be measured by Shannon entropy
Paper D
An Impact of Addressing Schemes on Routing Scalability

Figure 1: Address Label Distribution.
(Number of Covered Addr Labels for 3000 ASs)

354 144 124
11.8% 4.8% 4%
Paper D
An Impact of Addressing Schemes on Routing Scalability

Figure 3: Routing Table Size
(Number of Routing Entries for 3000 ASs)
Conclusions

1. develop distributed compact routing scheme
2. release some constraints imposed by the algorithm
3. gain some insights on the stability of compact routings
4. attempt to model the relation between routing scalability, addressing scheme and topology
5. However, there are still a lot of work left
   → do case study for the proposed routing model
   → BGP simulator with more features
   → study the relation of routing scalability, stability, convergence, routing stretch in a quantifiable manner
Thanks!