Investigating the Potential of the Inter-IXP Multigraph for the Provisioning of Guaranteed End-to-End Services

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1 Motivation: Inter-Domain Service Guarantees

> Modern applications demand end-to-end (QoS) guarantees:

□ High availability □ Low latency □ High bandwidth Low jitter, etc.

> Intra-domain QoS:

AS 2 DOMAIN AS 1 DOMAIN

4 Potential of CXPs on IXP Multigraphs

≻ ~5 IXPs cover:

□ ~40% of IPV4 space (directly)

□ ~91% of IPV4 space

(1-hop customer cone)

Effective incremental adoption of guaranteed e2e services





Inter-domain QoS: Very limited







- \succ One proposed solution \rightarrow path mediation
 - Logically centralized path brokers (using PCEs, SDN, etc.) [1]
 - □ ISPs provide QoS-enabled pathlets [2]
 - \Box Brokers stitch them end-to-end \rightarrow bandwidth markets, etc. [3]



> Mapped multigraph (based on EurolX dataset) \Box 229 IXP, 49k overlay (IXP_A, ISP_X, IXP_B) edges Up to 100s of distinct ASes (ISPs) between IXPs





- Generalized routing policies:
 - \Box Incentive \rightarrow anyone can provide a pathlet
 - Up to 29 times increase in path diversity over valley-free
 - □ Examples of policy generalization:
 - 1) valley-free with multi-IXP links
 - 2) extension of (1) with IXP links anywhere on the path

Pointy Peak CXP p2p



2 Observation: The Internet Gets Flatter over Time

Richer interconnectivity at IXPs [4]

- > Paradigm shift towards network virtualization and SDN [5]
- > IXPs adopt new technologies for their members **DE-CIX**

> Public IXPs are flourishing □ 100s of members, Tbps of traffic □ 100s of locations worldwide

- Concurrent peering of ISPs at multiple IXPs
- Constantly expanding peering ecosystem



3 Proposal: Control eXchange Points (CXPs) as Path Brokers over IXPs

- Good path diversity
- Maximal coverage of potential users



6 Path Stitching Algorithms over CXPs

- \succ Path stitching \rightarrow embedding problem: Embed e2e paths on inter-IXP multigraphs Subject to latency and bandwidth constraints
- > Our proposal [6]:



- □ Sample-select approach as heuristic online solution
- Use deterministic or randomized heuristics (dijkstra, random walks)
- □ Hybrid online-offline algorithms
- > Insights (full results at [6]):
 - □ Algorithms scale to the sizes of the multigraph
 - Diverse request mixes can be served
 - Performance comparison framework (acceptance ratios, embedding times, etc.)



□ Well-connected deployments □ High bandwidth and availability Provider neutrality

Open new TE possibilities across domains Deploy incrementally for maximum impact □ Use for inter-domain e2e QoS

> Nodes = IXPs (CXP switches)

Edges = inter-IXP pathlets • Over shared ISP members □ |Edges| >> |Nodes|



IXP

Evaluation code: <u>https://bitbucket.org/vkotronis/cxp_experimentation</u>

7 References

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