Improving Prediction Accuracy of Matrix Factorization Based Network Coordinate Systems

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Outline

- Introduction and Related Work
- Study on Prediction Accuracy for Short Links
- System Design of Pancake
- Performance Evaluation
- Conclusion

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Motivation

- Distance estimation can be used to optimize large scale distributed systems (P2P systems):
  - Server selection
  - Application level multicast/anycast
  - Overlay Routing
  - BitTorrent (P2P File Sharing)
- Problems with direct measurement:
  - Bad scalability: slow, high overhead

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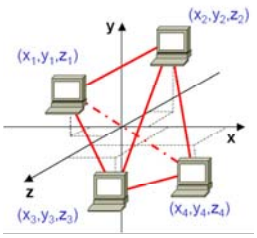
Background

- Network Coordinate (NC) systems: Lightweight and Scalable Internet distance prediction
  - Only requires O(N) measurements to predict the $N \times N$ distance of links
  - Just like a uniform, lightweight, high scalability real-time Internet Map with open API ☺



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Metric

- Relative Error
  - RE of the distance between host *i* and host *j* is defined as

$$RE = \frac{| M^E(i,j) - M(i,j) |}{min(M^E(i,j), M(i,j))}$$

where smaller RE indicates higher prediction accuracy. When the predicted distance equals to the measured distance, the RE value will be 0.

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Main Focus

- Prediction accuracy is vital for NC systems
- Breakthrough point
  - Relationship between link distance and relative error
  - MF based NC: Poor prediction accuracy of short links, i.e., the distances less than or equal to 50ms

✓We observed **similar phenomenon** while improving all the three MF based NC systems using our approach
✓Only the results with Phoenix are shown in this paper

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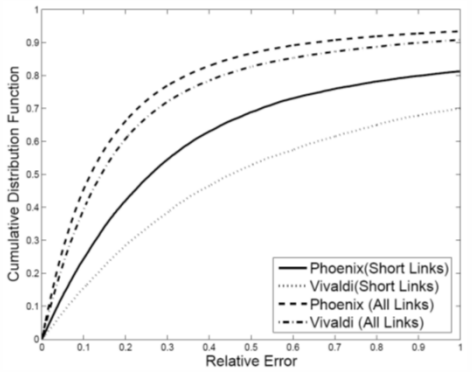
Relative Error of Short Links

* Vivaldi (ACM SIGCOMM'04) is the most widely NC system so far, which is based on Euclidean distance model



Target: reduce the prediction error of short links without increasing the prediction error of other links

Phoenix (All Links)	Vivaldi (All Links)	Phoenix (Short Links)	Vivaldi (Short Links)
0.67	0.92	3.37	5.20

90th Percentile RE (NPRE)

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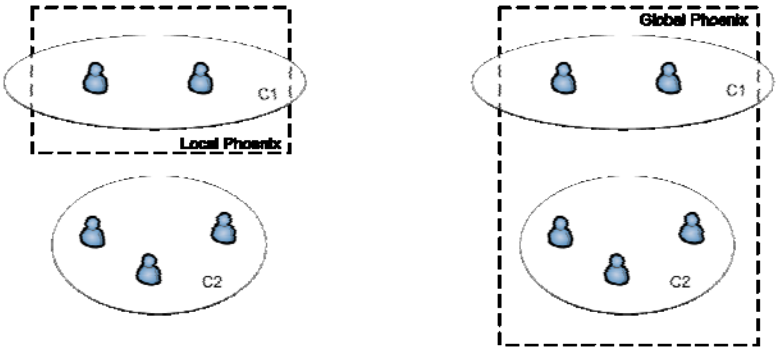
Local Phoenix vs Global Phoenix

*Suppose applications only interested in a **subset** of hosts, i.e., hosts in Germany*



Which way is more accurate??

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Decentralized Groupping

- Group these N hosts into u clusters in a decentralized way
  - Step 1: The u hosts are selected randomly as anchors among all N hosts, which will guide the decentralized clustering.
  - Step 2: For each ordinary host, it will measure its distance to every anchor and join the cluster represented by the nearest anchor.

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Median Distances: Intra and Inter Clusters

	C_1	C_2	C_3	C_4	C_5
C_1	39.63	79.63	54.06	160.16	54.41
C_2	79.63	51.74	98.21	181.65	66.14
C_3	54.06	98.21	28.06	122.06	85.33
C_4	160.16	181.65	122.06	53.65	190.63
C_5	54.41	66.14	85.33	190.63	27.16

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Local Phoenix vs Global Phoenix (cont.)

TABLE II
NPRE OF GLOBAL/ LOCAL PHOENIX (PLANETLAB DATA SET)

NC System \ Cluster	C_1	C_2	C_3	C_4	C_5
Host Amount	16	3	63	32	50
Global Phoenix	75.01	433.26	1.17	3.14	7.08
Local Phoenix	6.70	12.53	0.82	0.74	0.58

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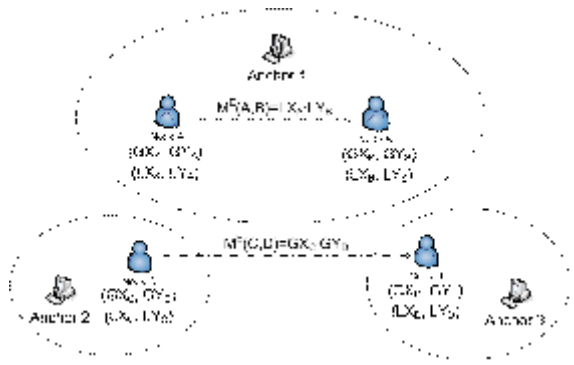
System Design of Pancake



$$M^E(i,j) = \begin{cases} LX_i \cdot LY_j & C_i = C_j \\ GX_i \cdot GY_j & C_i \neq C_j \end{cases}$$

Prediction of Intra Cluster Link: Local NC

Prediction of Inter Cluster Link: Global NC

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Extra Measurement Overhead

- For each ordinary host
  - measure its RTTs to every anchor once per hour
  - Compared with the measurement overhead for the NC calculation, it is negligible
- For the anchors
  - Anchors just need to be able to reply the ICMP PING passively, this causes very light load to the anchors
  - One million ordinary hosts in the system, the load of each anchor is approximately 2700 PINGs per second

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Performance Evaluation

- Relative Error of Distance Prediction
- Convergence Behavior of Pancake
- Evaluation through Dynamic Data Set

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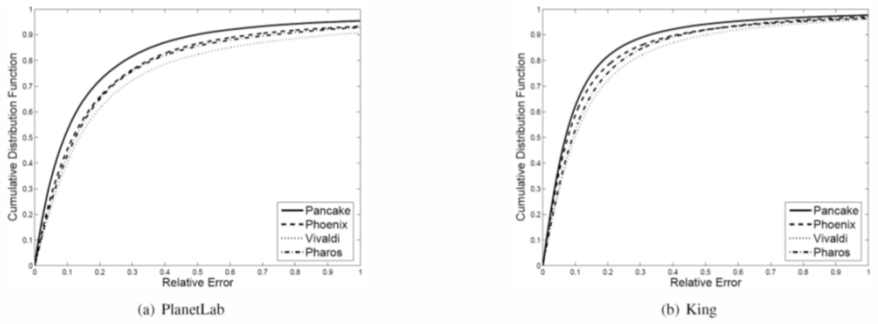
Relative Error



DataSet	Pancake	Phoenix	Pharos	Vivaldi
PL	0.50	0.67	0.73	0.92
King	0.33	0.41	0.44	0.50

90th Percentile RE

Dimension= 8, Reference Hosts = 32, Anchor Number = 5

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Main Contributions

- Intra Cluster MF based NC
  - Forming clusters in a decentralized way based on **locality**
  - Employing MF based NC algorithms such as Phoenix in **local clusters** achieves better prediction accuracy for intra-cluster links than merely relying on global NC algorithms.
- Pancake System
  - A two-level NC system which can significantly improve the **prediction accuracy** of existing NC systems
  - **Compatible** with existing deployments
  - **Negligible** extra communication overhead for end users
- Extensive Evaluation
  - Evaluation based on widely used real Internet data sets
  - Evaluation based on dynamic data set which reflects the RTT variations over time for all end-to-end links (first work to consider **RTT variations**)

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Future Work

- Theoretical study
  - Understand why the local NC can have better prediction accuracy
- Better decentralized clustering algorithm
  - Forming the clusters effectively and understand the relationship between cluster forming and prediction accuracy
- Applications
  - Potential applications: download mirror selection, match making in online gaming, server placement, etc...
- Extension for Capacity Estimation
- Experiments and Evaluation over PlanetLab and G-Lab

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