Towards Global Network Positioning

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New Challenges

• Large-scale distributed services and applications
  – Napster, Gnutella, End System Multicast, etc
• Large number of configuration choices
• K participants $\rightarrow O(K^2)$ e2e paths to consider
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Role of Network Distance Prediction

• On-demand network measurement can be highly accurate, but
  – Not scalable
  – Slow
• Network distance
  – Round-trip propagation and transmission delay
  – Relatively stable
• Network distance can be predicted accurately without on-demand measurement
  – Fast and scalable first-order performance optimization
  – Refine as needed
State of the Art: IDMaps [Francis et al ‘99]

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What Can be Improved?

- Scalability
- Speed
- Accuracy
Global Network Positioning (GNP)

- Model the Internet as a geometric space (e.g. 3-D Euclidean)
- Characterize the position of any end host with coordinates
- Use computed distances to predict actual distances
- Reduce distances to coordinates
Landmark Operations

Internet
• Small number of distributed hosts called Landmarks measure inter-Landmark distances
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- Compute Landmark coordinates by minimizing the overall discrepancy between measured distances and computed distances
  - Cast as a generic multi-dimensional global minimization problem
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Ordinary Host Operations

\begin{align*}
  &L_1, L_2, L_3 \\
  &\text{Internet}
\end{align*}

\begin{align*}
  &\text{(x}_1, y_1) \\
  &\text{(x}_2, y_2) \\
  &\text{(x}_3, y_3)
\end{align*}
• Each ordinary host measures its distances to the Landmarks, Landmarks just reflect pings
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GNP Advantages Over IDMaps

- High scalability and high speed
  - End host centric architecture, eliminates server bottleneck
  - Coordinates reduce $O(K^2)$ communication overhead to $O(K\times D)$
  - Predictions are locally and quickly computable by end hosts
- Enable new applications
  - Structured nature of coordinates can be exploited
- Simple deployment
  - Landmarks are simple, non-intrusive (compatible with firewalls)
Evaluation Methodology

- 19 Probes we control
  - 12 in North America, 5 in East Asia, 2 in Europe
- 869 IP addresses called Targets we do not control
  - Span 44 countries

- Probes measure
  - Inter-Probe distances
  - Probe-to-Target distances
  - Each distance is the minimum RTT of 220 pings
Evaluation Methodology (Cont’d)

• Choose a subset of well-distributed Probes to be Landmarks, and use the rest for evaluation
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Performance Metric

- Relative error
  - Symmetrically measure over and under predictions

\[
\frac{|predicted - measured|}{\min(measured, predicted)}
\]
GNP Accuracy

5-Dimensional Euclidean Space Model

Cumulative Probability

Relative Error
GNP vs IDMaps

5-Dimensional Euclidean Space Model

Cumulative Probability

Relative Error

GNP, 15 Landmarks
IDMaps, 15 Tracers
Why the Difference?

- IDMaps tends to heavily over-predict short distances
- Consider (measured $\leq 50$ms)
  - 22% of all paths in evaluation
  - IDMaps on average over-predicts by 150%
  - GNP on average over-predicts by 30%
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Summary

• Network distance prediction is key to performance optimization in large-scale distributed systems
• GNP is scalable
  – End hosts carry out computations
  – $O(K\times D)$ communication overhead due to coordinates
• GNP is fast
  – Distance predictions are fast local computations
• GNP is accurate
  – Discover relative positions of end hosts