CS 557
Landmark Routing

The Landmark Hierarchy:
A New Hierarchy For Routing in Very Large Networks
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Landmark Routing

• Objective:
  – Reduce the routing table size without increasing path length by a large amount

• Approach:
  – Select some routers as Landmarks
  – Construct a hierarchy of landmarks using increasing radius at each level
  – Name hosts/routers according to their proximity to landmarks.
Hierarchial Routing

• Distance Vector and Link State routing don’t scale to very large networks

• Hierarchial Approach to routing
  – Break the “flat” network into several pieces
  – Routing algorithm runs within a each piece
  – Routing algorithm run between different pieces
  – Can recursively break into more pieces to create more levels in the hierarchy.
Traditional Link-State Hierarchy

- Divide network into regions.
  - Router knows the full topology of its region.
  - Ex: router in region 2.2 knows full 2.2. Topology

- Router knows existence of other regions and border router.
  - Router in 2.2 knows region 2.1, region 1, and region 3 exist and how to reach them.
The Basic Trade-Off

• Each node knows only a limited amount of topological information:
  – A benefit for reducing routing table size, routing computation, number of updates, etc.

• Lack of full information results in some non-optimal routing choices.
  – Routers simply don’t know a shorter path exists because hierarchy limits topology information stored at a given node.
Routing in The Hierarchy

Routing follows the hierarchy and results in 7 hop path

Shortest path if all routers know full topology is 4 hops
The Landmark Hierarchy

• Associate a level and a radius with every router.

• Level 0 router
  – Every router within radius $r_0$ knows how to reach this router
  – Can reach at least one Level 1 router

• Similar for Level 1, Level 2, …, Level $H$
  – Every router can reach Level $H$ router
  – In other words $r_H = \text{network diameter}$.
Example Landmarks

Figure 3: Landmark Hierarchy
Addressing in the Landmark Hierarchy

• Associate each node with a sequence of Landmarks that lead to the node.
  – Start with a Level H landmark
  – Next select a Level H-1 landmark
  – Next select a Level H-2 landmark
  – ....
  – Finally select a Level 0 landmark.

• Require that source within radius of Level 0 landmark, Level 1 landmark within radius of Level 0 landmark, etc.
Landmark Example
Landmark Example

Routing Table at G:
LM2[d]  2   F
LM1[l]  1   K
Lm0[e]  0   F
LM0[k]  0   K
LM0[f]  0   F

Path from G (d.i.g) to T (d.n.t)
is: G-F-E-D-U-T

Shortest Path is:
G-K-I-U-T
Some Advantages of Landmarks

- Limits amount of storage space required at each router.
  - Comparable to link-state areas.

- Can dynamically elect landmarks
  - Harder to dynamically select link-state areas

- Path to destination does not go through each landmark
  - Always use border routers in link-state hierarchy.
Performance

• Definitions
  – $r_i = \text{landmark radius} = \text{distance that a level } i \text{ landmark can be seen}$
  – $d_i = \text{distance from router to nearest level } i \text{ landmark}$

• Observations
  – Increase in $R \Rightarrow$
    • Increase in routing table size (more landmarks visible in table)
    • Decreases path lengths (switch to level faster)
  – More landmarks at level $i \Rightarrow$ router closer to landmark at level $i \Rightarrow d_i \text{ smaller}$
  – $r(i-1) \text{ must be big enough to cover nearest } i \text{ landmark, } d_i \text{ smaller } \Rightarrow \text{ can decrease } r(i-1)$
Performance Results

• Depends on ratio $r/d$
Toward Global Internet Routing

• Global Internet is a two-level hierarchy
  – Divide the network into autonomous systems
  – CSU is an AS, AT&T is an AS, etc.

• Within an AS
  – Typically distance vector or link state routing
  – Choice is entirely up to local AS

• Between different Autonomous Systems
  – Distance vector?
  – Link State?
  – Landmarks?
  – Something else?