Object Location

- Problem: Find a close copy of an object in a large network
- Solution should:
  - Find object if it exists
  - Find a close copy of the object (no round trip to Siberia to find an object next door)
  - Balance the load
  - Handle changing participant set

Tapestry: Motivation and Algorithms

Two Simple Solutions

- Solution 1: One central directory
  - Must travel far even for nearby objects
  - Load not balanced
- Solution 2: Every node has a directory.
  - Very expensive to add an object to system
  - (but has locality!)

Better Solution: Hierarchy

- Have many levels of directories
  - Check lowest, then second lowest, and so on until the highest.
  - Many low-level directories, one highest level
  - If object is nearby, it is found quickly
- Problems
  - How to build hierarchy? Assume info given?
  - How to load balance?

Random Hierarchy

- At random
  - 1 in 16 nodes level-1 directories.
  - 1 in 256 level-2 directories
  - …
  - Closest level-1 node is your “local” directory
- Load Balance
  - Create 16 types of level-1 directories
  - Create 256 types of level-2 directories
  - …

Tapestry! [PRR]

- Nodes are directories. Node with ID 1234 is a 1 directory, 12 directory, 123 directory….
- Object 5678 is found in closest 5 directory, closest 56 directory, …
- (Cannot do quite this—tables would be too large.)

How Does Tapestry Fit?

System	Insertion	Find	Locality	Balanced
Central Directory	O(1)	O(1)	Yes	No
No directory	> O(n)	O(1)	No	Yes
CAN	O(r)	$O(rn^{1/r})$	No	No
Chord	$O(\log^2 n)$	O(log n)	No	Yes
Pastry	$O(\log^2 n)$	O(log n)	Maybe	Yes
Tapestry	$O(\log^2 n)$	O(log n)	Some	Yes

Insertion

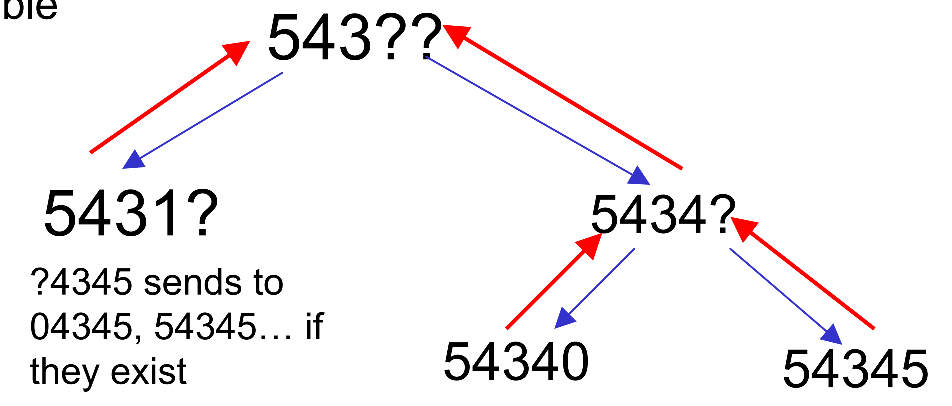
- Find node with closest matching ID (surrogate) and get preliminary neighbor table
- Find all nodes that need to route to new node via multicast
- Optimize neighbor table

Acknowledged Multicast Algorithm

Locates & Contacts all nodes with a given prefix

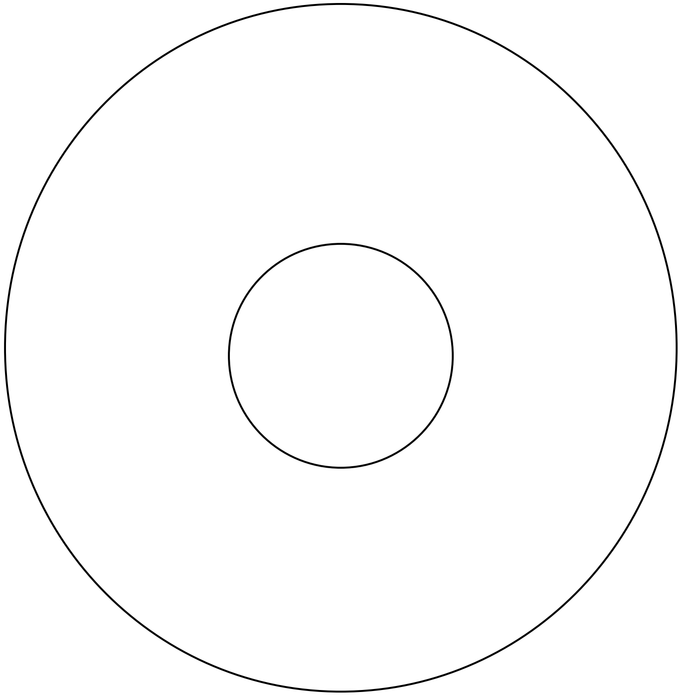
- Create a tree based on IDs as we go
- Starting node knows when all nodes reached
- Nodes send acks when all children reached

The node then sends to **any** ?0345, **any** ?1345, **any** ?3345, etc. if possible



Optimize Neighbor Table

- Idea:
  - Given level-i list, find all level-(i-1) pointing to level-i list.
  - Trim list
  - Repeat
- Level-(i-1) node in little circle must must point to a level-I node in the big circle



Simultaneous Insertions

- Two nodes *conflict* if there no is ordering the network can agree on.
  - A arrives *before* B one place, but *after* B some other place
- Modify multicast algorithm so two conflicting nodes find each other.
  - Send down hole being filled (same hole)
  - Send down “watch list” of prefixes (diff hole)
- Nodes getting multicast
  - If node on watchlist found, forward information
  - If hole already filled, send to all such nodes

Locking Pointers

- Multicast assumes that chosen node can forward message.
- Inserting nodes have incomplete information.

So…

- Pointers are added as “locked”. When multicast for that node returns, pointers are unlocked.
- Multicasts are sent to one unlocked pointer and all locked pointers.
- Locked pointers may not be deleted.