Chord: A Scalable Peer-to-peer Lookup Protocol for Internet Applications

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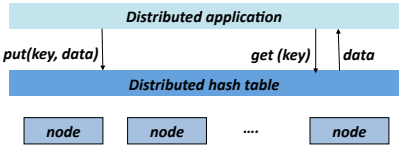
Background

- We studied P2P file sharing in class
  - Napster
  - Gnutella
  - KaZaA
  - BitTorrent
- Today, let's learn more!
  - **Chord**: a scalable P2P lookup protocol
  - **CFS**: a distributed file system built on top of Chord
  - http://pdos.csail.mit.edu/chord

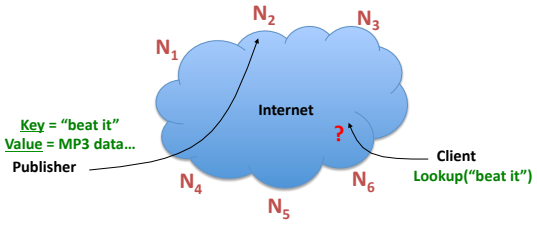
Review: distributed hash table



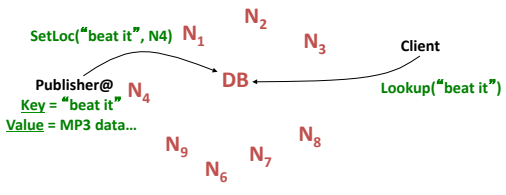
DHT provides the information look up service for P2P applications.

- Nodes uniformly distributed across *key* space
- Nodes form an *overlay* network
- Nodes maintain list of neighbors in routing table
- Decoupled from physical network topology

The lookup problem

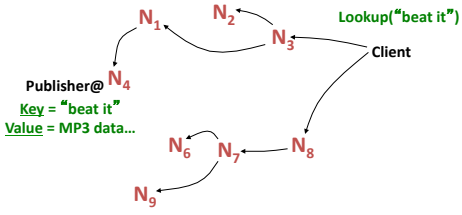


Centralized lookup (Napster)



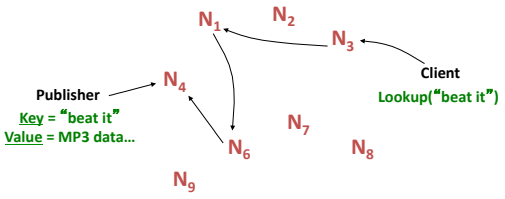
Simple, but O(*N*) state and a single point of failure

Flooded queries (Gnutella)



Robust, but worst case O(*N*) messages per lookup

Routed queries (Chord)



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Routing challenges

- Define a useful key nearness metric
- Keep the hop count small
- Keep the tables small
- Stay robust despite rapid change

- **Chord**: emphasizes efficiency and simplicity

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Chord properties

- Efficient: O(*log(N)*) messages per lookup
  - N is the total number of servers
- Scalable: O(*log(N)*) state per node
- Robust: survives massive failures

- Proofs are in paper / tech report
  - Assuming no malicious participants

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Chord overview

- Provides peer-to-peer hash lookup:
  - Lookup(key) → return IP address
  - Chord does not store the data
- How does Chord route lookups?
- How does Chord maintain routing tables?

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Chord IDs

- Key identifier = SHA-1(key)
- Node identifier = SHA-1(IP address)
- Both are uniformly distributed
- Both exist in the same ID space

- How to map key IDs to node IDs?
  - The heart of Chord protocol is "**consistent hashing**"

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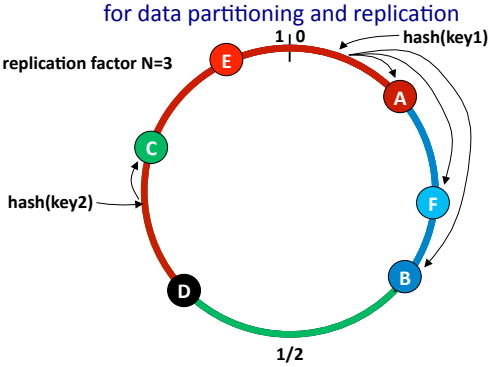
Review: consistent hashing

for data partitioning and replication



A key is stored at its successor: node with next higher ID

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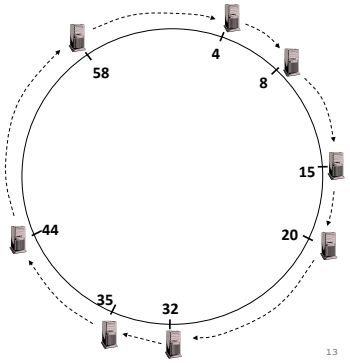
Identifier to node mapping example

- Node 8 maps [5,8]
- Node 15 maps [9,15]
- Node 20 maps [16, 20]
- …
- Node 4 maps [59, 4]

- Each node maintains a pointer to its successor



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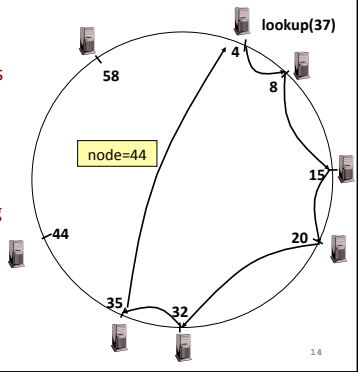
Lookup

- Each node maintains its successor
- Route packet (ID, data) to the node responsible for ID using successor pointers



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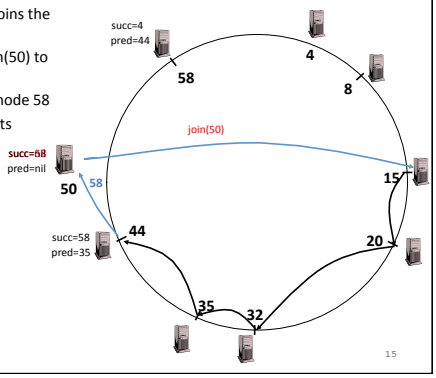
Join Operation

- Node with id=50 joins the ring via node 15
- Node 50: send join(50) to node 15
- Node 44: returns node 58
- Node 50 updates its successor to 58



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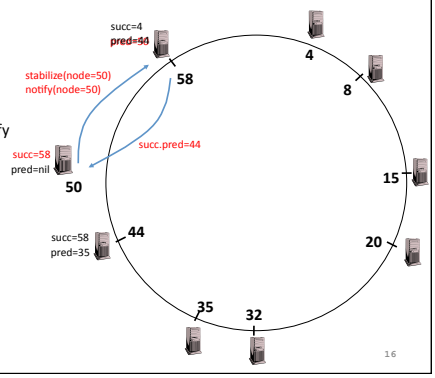
Periodic Stabilize

- Node 50: periodic stabilize
  - Sends stabilize message to 58
- Node 50: send notify message to 58
  - Update pred=44



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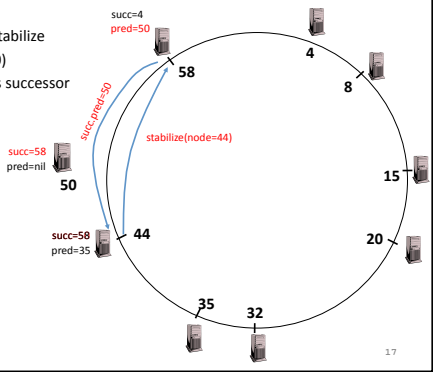
Periodic Stabilize

- Node 44: periodic stabilize
- Asks 58 for pred (50)
- Node 44 updates its successor to 50



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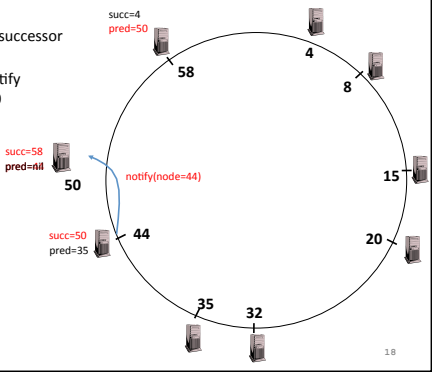
Periodic Stabilize

- Node 44 has a new successor (50)
- Node 44 sends a notify message to node 50



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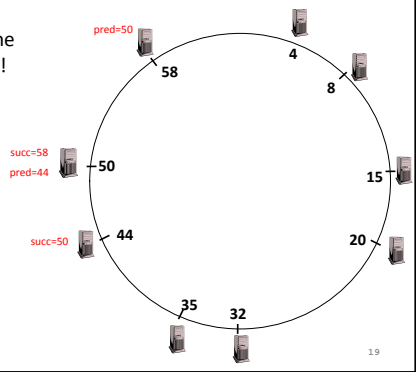
Periodic Stabilize Converges!

- This completes the joining operation!

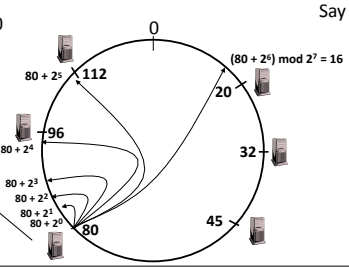


Achieving Efficiency: *finger tables*

Say $m=7$

Finger Table at 80

i	$ft[i]$
0	96
1	96
2	96
3	96
4	96
5	112
6	20



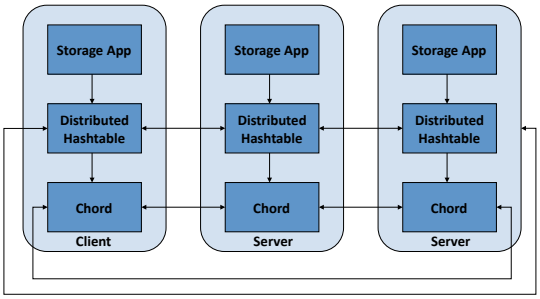
*i*th entry at peer with id *n* is first peer with id >= $n + 2^i \pmod{2^m}$

- Each node only stores *O*(log *N*) entries
- Each look up takes at most *O*(log *N*) hops

Achieving Robustness

- What if nodes FAIL?
- Ring robustness: each node maintains the k (> 1) immediate successors instead of only one successor
  - If smallest successor does no respond, substitute the second entry in its successor list
  - Unlikely all successors fail simultaneously
- Modifications to stabilize protocol (see paper!)

Example of Chord-based storage system



Cooperative File System (CFS)

Block storage
Availability / replication
Authentication
Caching
Consistency
Server selection
Keyword search

} DHash distributed block store

Lookup } Chord

- Powerful lookup simplifies other mechanisms

Cooperative File System (cont.)

- Block storage
  - Split each file into blocks and distribute those blocks over many servers
  - Balance the load of serving popular files
- Data replication
  - Replicate each block on ***k*** servers
  - Increase availability
  - Reduce latency (fetch from the server with least latency)

Cooperative File System (cont.)

- Caching
  - Caches blocks along the lookup path
  - Avoid overloading servers that hold popular data
- Load balance
  - Different servers may have different capacities
  - A real server may act as multiple *virtual servers*, by being hashed to several different IDs.

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Q & A

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