MapReduce on a Chord Distributed Hash Table

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Background

- Google's MapReduce [1] paradigm is integral to data processing.
- Popular platforms for MapReduce, such as Hadoop [2], are designed to be used in datacenters with a degree of centralization.
- Until recently, analysis and optimization of MapReduce has largely remained constrained to that context.

Goals

- We wanted build a more abstract system for MapReduce.
- We remove core assumptions [3]:
  - The system is centralized.
  - Processing occurs in a static network.
- The resulting system must be:
  - Fault tolerant.
  - Scalable.
  - Completely decentralized.

Features of ChordReduce

ChordReduce is a decentralized framework for distributed computing:

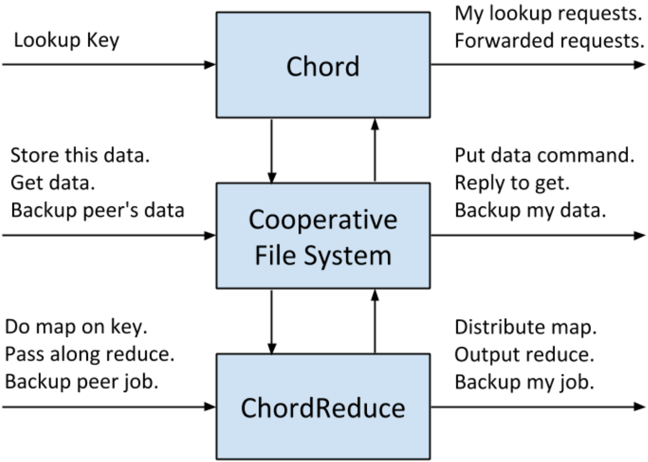
- Scalable.
- Load-Balancing.
  - Data and tasks are evenly distributed across the network.
  - Joining nodes are automatically assigned data and tasks.
- Decentralized:
  - No centralized node is needed to maintain metadata.
  - No central coordinator for tasks.
- Fault tolerant:
  - The loss of multiple nodes does not impact integrity.
  - The network can adjust to churn, the effects of nodes entering and leaving.

System Architecture

ChordReduce has three layers:

- Chord [4], which handles routing and lookup.
- The Cooperative File System (CFS) [5], which handles storage and data replication.
- The MapReduce layer.

System Architecture



Chord

Chord is a peer-2-peer lookup service, where the nodes in the network are arranged in a ring overlay.

- Nodes and files are assigned an m-bit key (typically $m = 160$).
- Nodes know their predecessor and successor in the ring.
- Nodes are responsible for files with keys between their predecessor's key and their own key.
- To speed routing, nodes maintain a table of m shortcuts, called fingers.
- The fingers allow a high probability $\log_2 N$ lookup time for any key.

A Chord Network

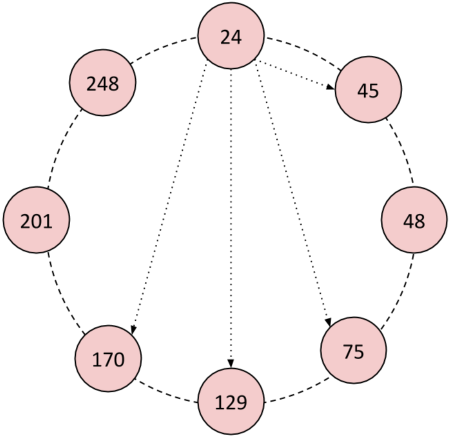


Figure: An 8-node Chord ring where $m = 8$. Node 24's fingers are shown.

CFS

The Cooperative File System runs on top of Chord.

- Files are split up, each block given a key based on their contents.
- Each block is stored according to their key.
- The hashing process guarantees that the keys are distributed near evenly among nodes.
- A keyfile is created and stored where the whole file would have been found.
- To retrieve a file, the node gets the keyfile and sends a request for each block listed in the keyfile.

Fault Tolerance

- Each node maintains a list of its s closest successors.
- Nodes back up data they're responsible for to their successors.
- When a node's predecessor fails, the node can immediately take over.
- If a node detects a new predecessor, it sends the predecessor all the data it should be responsible for.

Mapping Data

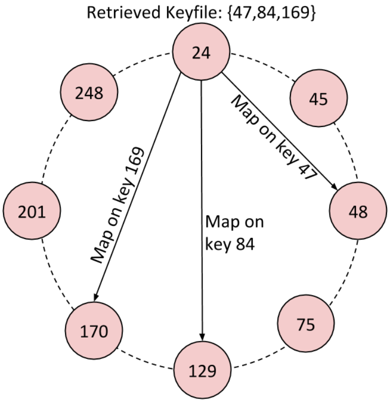


Figure: The stager sends a map task for each key in the keyfile. In larger networks, this process is streamlined by recursively bundling keys and sending them to the best finger.

Reducing Results

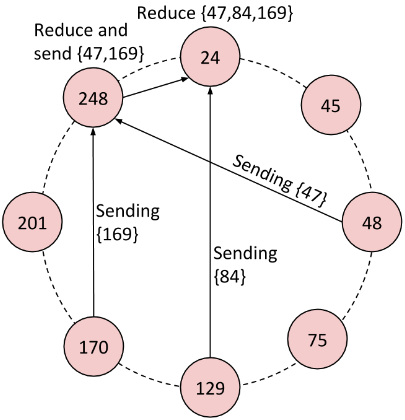


Figure: Results are sent back via the overlay. If a node receives multiple results, they are reduced.

Fault Tolerance of Map Jobs

- Each node backups their map tasks; removes it when the task is processed.
- If the immediate successor detects the node's failure, it takes over the task.
- If a node detects a new predecessor responsible for a key and map task pair in it's queue, it sends it to the predecessor.
- This allows node to further distribute the work during execution.

Fault Tolerance of Reduces

- Individual reduces are backed up in a similar manner; if the original holder of the reduce fails before the reduce is sent, his successor sends his backup.
- Results are sent back to a key, rather than to a specific node.
- This ensures that if node receiving the data fails, his successor will take over.

Experiment Details

Our initial test was a Monte Carlo approximation of π.

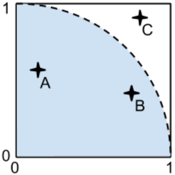


Figure: The node chooses random x and y between 0 and 1. If $x^2 + y^2 < 1^2$, the "dart" landed inside the circle.

- Map jobs were sent to randomly generated hash addresses.
- The ratio of hits to generated results approximates $\frac{\pi}{4}$.
- Reducing the results was a matter of combining the two fields.

Variables

We ran the experiment using Amazon's Elastic Cloud Compute [6] and varied the following:

- Network size.
- Problem size.
- Rate of churn.

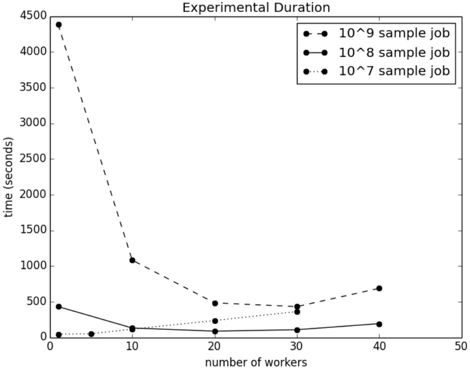


Figure: For a sufficiently large job, it was almost always preferable to distribute it. When the job is too small, such as with the 10^7 data set, our runtime is dominated by the overhead. Our results are what we would expect when overhead grows logarithmically to the number of workers.

Churn Results

Churn rate per second	Average runtime (s)	Speedup vs 0% churn
0.8%	191.25	2.15
0.4%	329.20	1.25
0.025%	431.86	0.95
0.00775%	445.47	0.92
0.00250%	331.80	1.24
0%	441.57	1.00

Table: The results of calculating π by generating 10^8 samples under churn. Churn is the chance for each node to join or leave the network. The large speedup is from joining nodes acquiring work during experimental runtime.

Conclusions

Our experiments established:

- ChordReduce can operate under high rates of churn.
- Execution follows the desired speedup.
- Speedup occurs on sufficiently large problem sizes.

This makes ChordReduce an excellent platform for distributed and concurrent programming in cloud and loosely coupled environments.

Questions?

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"Virtual hadoop," http://wiki.apache.org/hadoop/Virtual

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