CS554: FusionFS Basics

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September 2013

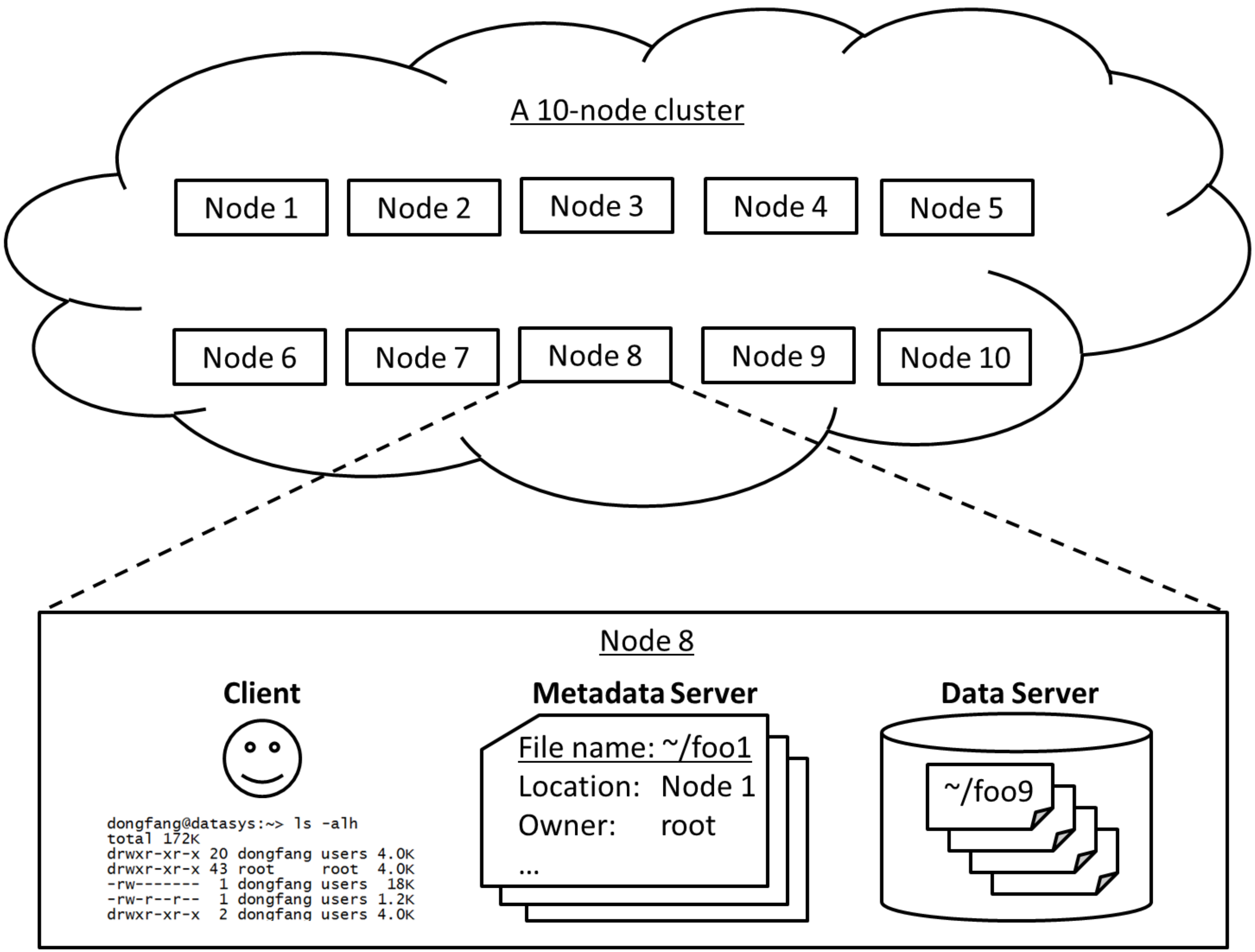
Motivation

- How to achieve scalable I/O throughput for extreme scale distributed systems. Examples:
  - In cloud computing, metadata is a bottleneck
  - In high-performance computing, storage is remotely connected

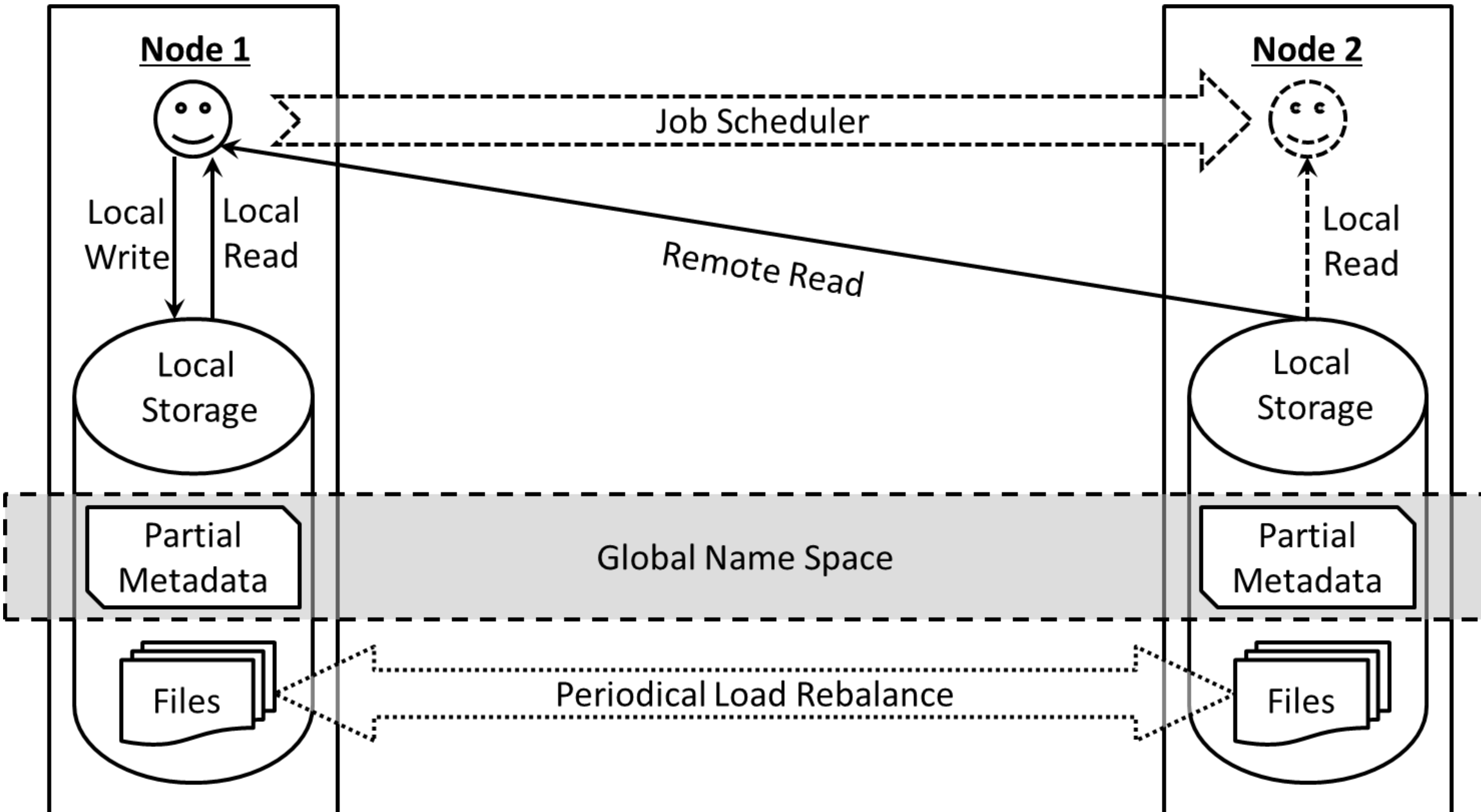
Goal

- Propose a new storage architecture to achieve high I/O throughput at extreme scale:
  - Metadata management
    - Co-locate to computation
    - Evenly distributed on compute nodes
  - Data movement
    - Co-locate to computation
    - Write: to local disk; rebalancing
    - Read: schedule the job to the data; or transfer the data

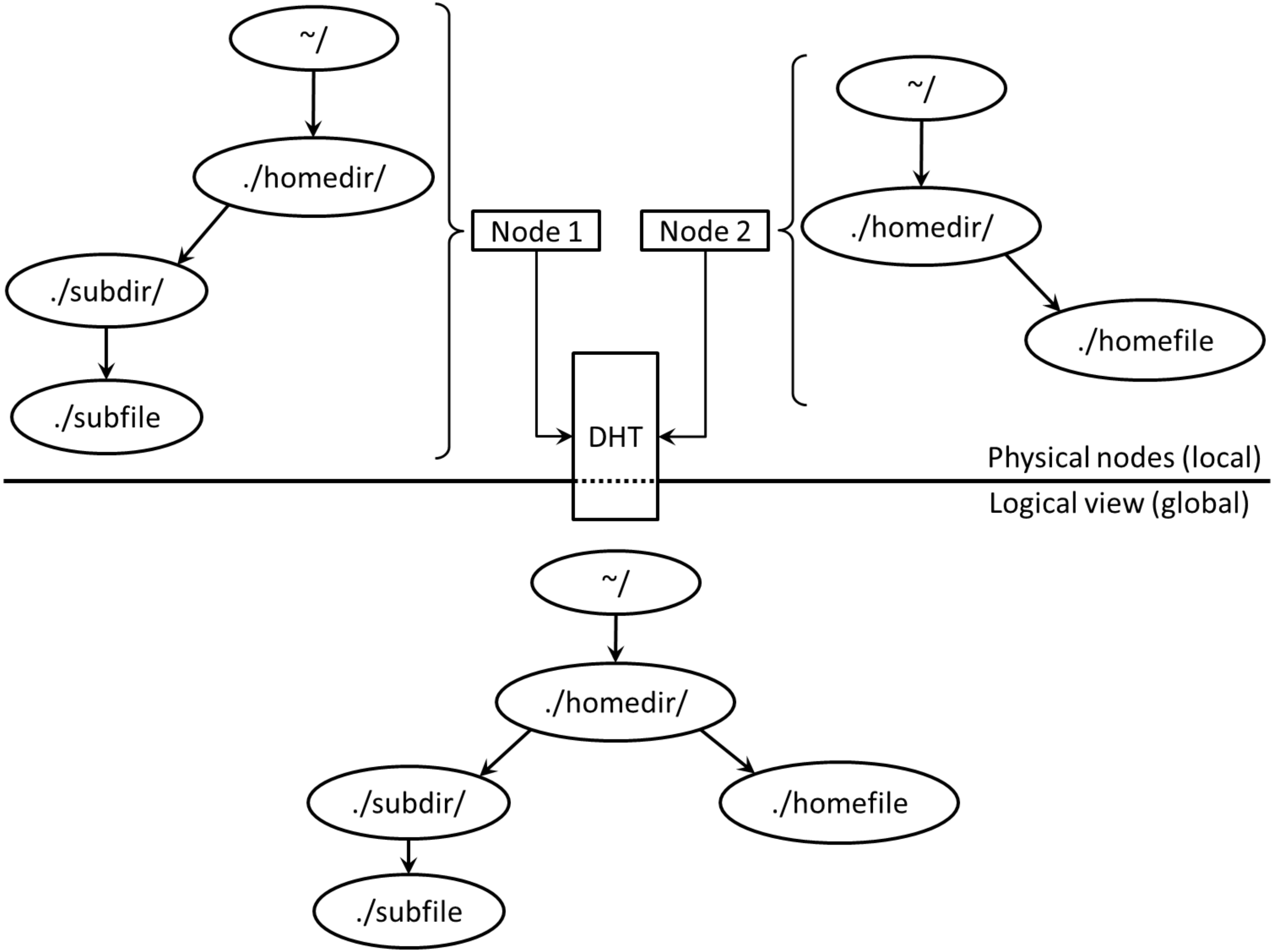
Roles


A 10-node cluster
Node 1
Node 2
Node 3
Node 4
Node 5
Node 6
Node 7
Node 8
Node 9
Node 10
Node 8
Client
dongfang@datasys:~> ls -alh
total 172K
drwxr-xr-x 20 dongfang users 4.0K
drwxr-xr-x 43 root root 4.0K
-rw------- 1 dongfang users 18K
-rw-r--r-- 1 dongfang users 1.2K
drwxr-xr-x 2 dongfang users 4.0K
Metadata Server
File name: ~/foo1
Location: Node 1
Owner: root
...
Data Server
~/foo9

Architecture



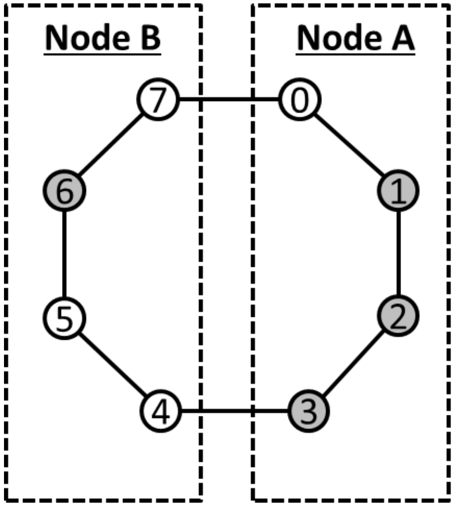
Global Name Space



Distributed Hash Table

Key	Value
~/	drwxrwxr-x; 4.0K; ~/homedir/subdir
~/homedir	drwxrwxr-x; 4.0K; ~/homedir/subdir, ~/homedir/homefile
~/homedir/subdir	drwxrwxr-x; 4.0K; ~/homedir/subdir/subfile
~/homedir/homefile	-rw-rw-r--; 423M; Node 1
~/homedir/subdir/subfile	-rw-rw-r--; 133M; Node 2
⋮	⋮

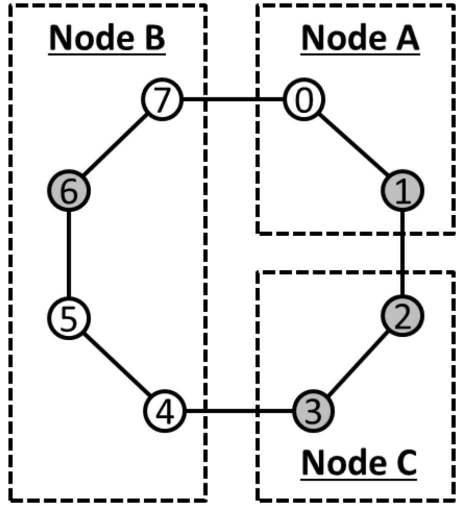
Resilience



Membership Table

Start	Node	Entries
0	A	1, 2, 3
4	B	6

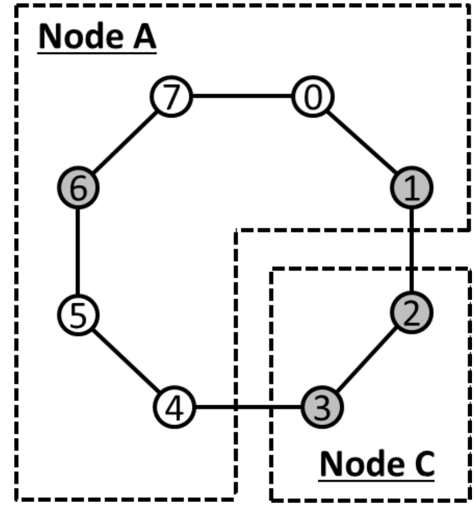
Stage 1: initial state



Membership Table

Start	Node	Entries
0	A	1
2	C	2, 3
4	B	6

Stage 2: Node C joins



Membership Table

Start	Node	Entries
2	C	2, 3
4	A	6, 1

Stage 3: Node B leaves

Data Movement

- Design principle
  - Always write to the local compute node
    - Pro: maximal aggregate throughput
    - Con: bad load balance
      - Possible solution: Asynchronous rebalancing?
  - No locality-awareness for data read
    - Transfer from the node that has the file
      - Maybe it is just loopback if we are lucky
      - Can we schedule the job on the node with the required data?
    - Then read locally

Data Replication

- Design principle
  - Option 1: traditional replicas
    - Pro: ease-of-use
    - Con: low storage utilization
  - Option 2: information dispersal algorithms (e.g. erasure coding)
    - Pro: small storage overhead
    - Con: compute intensive
      - Solution: GPU acceleration?

Data Provenance

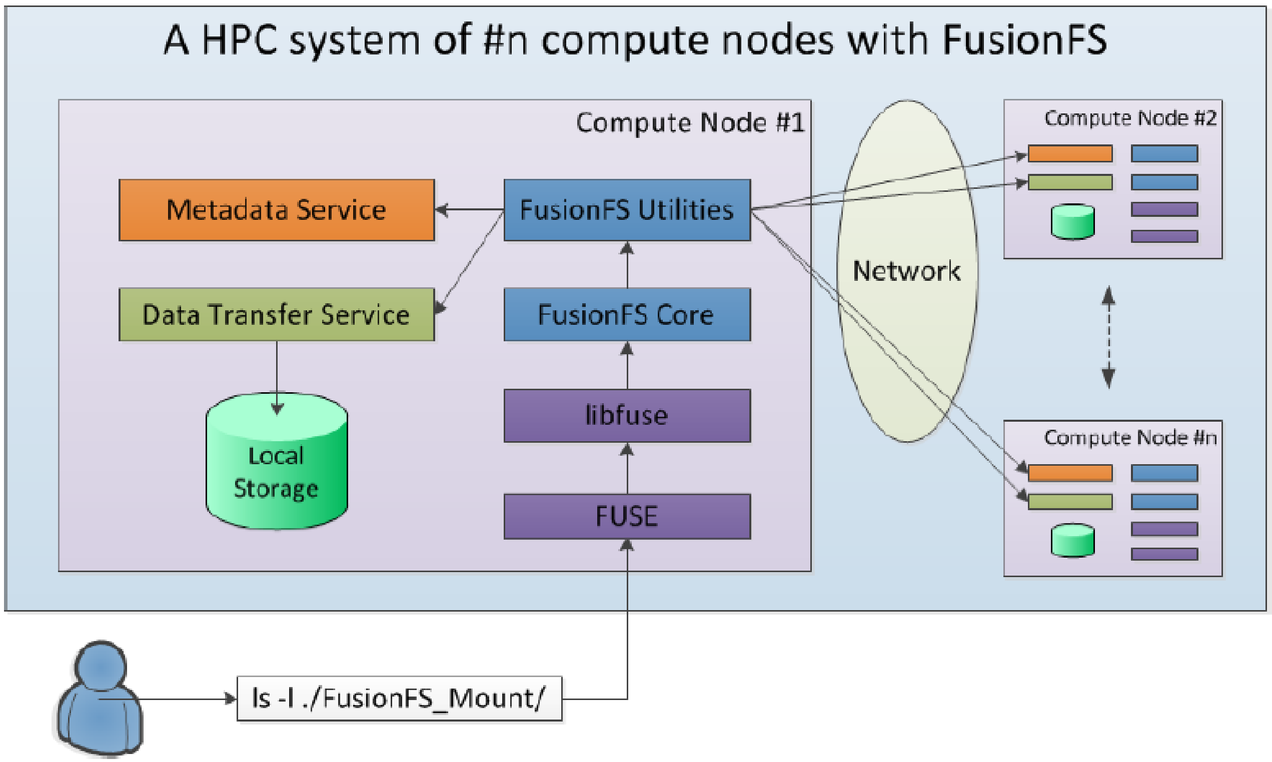
- Design principle
  - Provenance data saved on compute nodes
  - Independent to file metadata
  - Provide a hybrid of fine- and coarse-grained levels of provenance
    - A summary of block-level provenance, as well as the file-level provenance

Data Compression

- Design principle
  - Customizable: users should be able to specify/choose which compression algorithms to be applied
  - Resilient: should apply different strategies for different type/size of files
  - Transparent: the compression should not require any modification to the applications and/or high level I/O libraries

Implementation

- Implementation
  - C, C++, Shell script, FUSE, socket, Pthread



FusionFS Projects

- More information from Prof. Raicu
- My suggestions in general:
  - Strong programming skills in
    - System programming in C
    - Scripting language, e.g. Shell script, perl, python
  - Familiar with at least one distributed file system, e.g. HDFS, GPFS, Lustre, PVFS
  - Knowledgeable in distributed systems and operating systems (CS550 is a good sign)
  - Comfortable with Linux terminals, e.g. vi, ssh, scp

Questions

- FusionFS document: http://datasys.cs.iit.edu/~dongfang/download/FusionFS-TR-IIT-CS-2013-08.pdf
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