OVERCOMING METADATA BOTTLENECKS: SCALABLE HDFS
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SINGLE METADATA SERVER LIMITATIONS

- Throughput limitations with one node
- Metadata operation and block allocation
- High rates of metadata operations for small files – intensive workloads
- Total number of files is limited by memory size
- Follow GFS design to simplify and accelerate code path
- Easy fix with disk data structures, but much lower throughput

OUR GOALS

- Increase metadata operation throughput
- Use multiple servers and avoid hot spot
- Low latency
- When metadata fit in memory, as low as single server
- High availability and fault tolerance
- Explore tradeoffs for solving metadata bottleneck with table stores
- Characterize table store features and implementations capable for scalable metadata service

OPENCLOUD METADATA OPERATION STATS

- open() is dominant operation
- Most list operations only involve a few files
- Path name length is mostly 5-10
- May want to reduce iterative lookups for each path name component

WHY USE SCALABLE DB?

- Benefits:
  - Use multiple machines’ CPU, memory, disks
  - Support backend storage with disks
  - Powerful and flexible DB code already exists
- Risks:
  - One RPC to NN may end up being many RPCs
  - Data in NN’s memory will be spread out
  - Longer latency because of disk accesses
  - Longer code path with unneeded functionality

ROW KEY SCHEMAS

- DB fetch brings in multiple rows
- So, what access patterns use the rest of each fetch?
- B-tree sorts on:
  - Full path name + one table lookup for each file
  - locality for whole subdirectory
  - rename a directory
- Directory depth + full path name + locality for every directory
- Parent Inode + file name (Inode + FN)
  - multiple lookups for each file
  - rename only changes inode
- Hash(path name): Better load balance
  - load balanced

INTERESTING CHALLENGES

- Trade-offs in file metadata table schema
- Optimization for group operations such as rename a directory could hurt a lookup operation
- Indirection causes more lookups than full pathname
- Maximizing locality leads to load imbalance
- Use data duplication to optimize for different access patterns
- Columnar store
  - Locality group based on access pattern
  - Reduce clean up work such as major compactions
- Reduce latency caused by distributing metadata
  - Collocate processes with tablet server
- Coprocessor in HBase, Iterator in Accumulo
  - Send requests in parallel
- Aggressive caching is feasible if clients can tolerate temporary outdated data
- Efficient use of memory
- Memory overhead compared to customized service