Finding a Needle in a Field of Haystacks

Lightweight Metadata Search for Large-Scale Distributed Research Repositories

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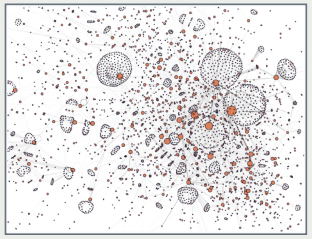
1 ABSTRACT

- Fast, scalable, and distributed search services are increasingly available to organizations with large volumes of data to index, but often require that data be located centrally
- Globus, a distributed network for fast file transfers, lacks an efficient means for search
- Our solution: a two-level tree of lightweight metadata indexes that retains summary terms able to reference data while drastically reducing the amount of data stored centrally by upwards of 96% in all tests — a "second-level index" (SLI)

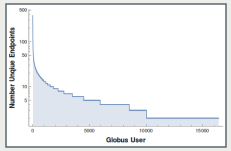
2 GLOBUS



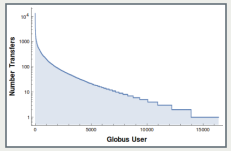
Globus file transfer network [1]. Nodes represent endpoints, scaled by data size, edges represent transfers (length is inversely proportional to transfer volume).

Globus by the Numbers

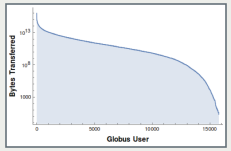
- 256 PB transferred
- 36 billion files processed
- 1 PB — largest single transfer to date
- 10,000 active endpoints
- 56,000 registered users
- 10,000 active users/year



Unique endpoints per Globus user



Number of transfers per Globus user



Bytes transferred per Globus user

Why metadata?

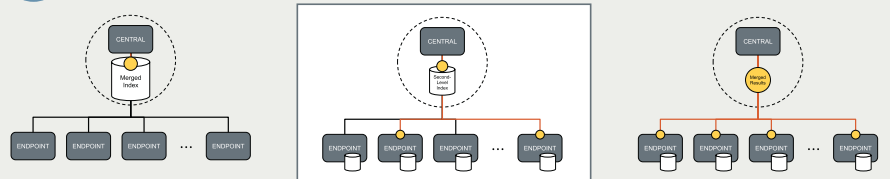
- Globus connects research repositories, many of which contain files that are not full text or easily indexable
- In such repositories, files are often characterized by long names and directory paths rather than contents
- Metadata is much easier to work with at scale — and Globus is huge

Which data?

- 37 largest public Globus endpoints (2.7 TB total)
- NERSC filesystem dump, similar to large private endpoints (164.6 TB total)

(Globus network images courtesy of William Agnew, Georgia Institute of Technology.)

3 DESIGN/SETUP



Traditional 1: single central index

DESCRIPTION
- Central index is result of merging indexes from each endpoint

ADVANTAGES
+ Users only need to store indexes when the endpoint's file system is updated

PROBLEMS
- Central index must store references to documents on endpoints (grows too fast)
- Heavy central storage burden

Our Method: hierarchical hybrid featuring "collapsed" second-level index (SLI)

- SLI references endpoints, and contains a summary subset of indexed terms
+ Some storage burden on users, but still very low per user
+ Lower storage burden on central servers
+ SLI returns a smaller subset of endpoints to which queries must be distributed

Traditional 2: fully distributed index

DESCRIPTION
- Indexes kept on each endpoint
- Central servers distribute query to each endpoint, then retrieve/merge results

ADVANTAGES
+ More space taken up by indexes than Method 1, but burden is split among users

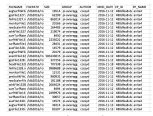
PROBLEMS
- Most search terms are likely to correspond only to a small subset of endpoints

Indexing with Xapian

- Xapian is an open-source indexing engine for full-text search with strong Python support
- We added new tokenization capabilities to allow it to interpret terms from filepaths, camel-case filenames, etc.
  `"IAmManyTerms.csv" -> F:'I',Am',Many',Terms'; E: 'csv'`
- Numerical metadata (sizes, datetimes) were indexed for range searches

NERSC FS Data Prep

- File system dump from February 2017
- Crawled FS and extracted metadata
- Divided metadata by "project," then binned into 8 equal-sized shards
- Distributed across 8 VM "endpoints"
- Binning by project prevents "endpoints" from being too similar



Sample metadata

4 RESULTS (PUBLIC ENDPOINTS)

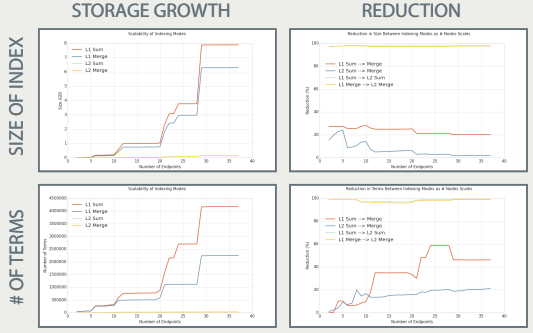
SLI Performance

	Level 1 Terms	Level 2 Terms	Reduction
Sum	11,602,821	59,983	99.48%
Merge	8,244,805	5,155	99.94%
Reduction	28.94%	91.41%	

SLI Performance (above)
- "Sum": sum of terms in all individual indexes
- "Merge": terms in the single merged index (built from individual indexes)

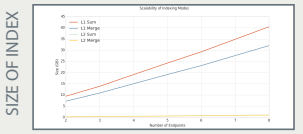
SLI Scalability (right)
- x-axis: number of endpoints (in arbitrary order) used to build the merged index
- Note: in "Storage Growth" graphs, the yellow line showing scalability of second-level index (sum) exactly overlaps green line (merge)

SLI Scalability



5 RESULTS (NERSC FS)

STORAGE GROWTH



Term Dist. Over Endpoints

- The majority of terms indexed from filename and pathname metadata appear only on a subset of the endpoints
  - 60.3% of terms exist on one
  - 76.3% of terms exist on two
  - Only 2.1% of terms exist on all
- NERSC FS results are conservative estimates due to similarity
- In general, very few terms will be represented on all endpoints, making the fully distributed model inefficient (very low precision)

SLI Performance

	Lvl 1 Size (GB)	Lvl 1 Size (GB)	Reduction
Sum	39.51	1.08	97.27%
Merge	31.29	0.99	96.83%
Reduction	20.80%	7.78%	

Size reduction is still very high for the NERSC filesystem. Note also that gains from simply merging endpoint-level indexes are only 20.08%, underscoring infeasibility of single central index.

6 CONCLUSIONS

- Our second-level index (SLI) finds a workable compromise between the two traditional large-scale indexing architectures
- The SLI algorithm dramatically reduces the size of a central merged index
  - By using two levels and referencing endpoint-level indexes, the central index can avoid storing all terms, instead only extremely stemmed terms and numerical ranges
  - Because full indexes are retained on endpoints, search is still accurate once redirected to those endpoints
  - Recall stays ~1 because queries at SLI level are stemmed the same as terms. Precision is higher than Traditional Method 2.
- Allows for greater scaling and potentially makes the difference between indexing in memory (fast) and indexing on disk (slow)

7 ACKNOWLEDGEMENTS

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9 REFERENCES

1. Foster, Ian. "Globus Online: Accelerating and democratizing science through cloud-based services." IEEE Internet Compu ng 15.3 (2011): 70.