Fusing
Data Management Services with File Systems

(A Vision by Database & File System Researchers)

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Introduction

- Data is growing fast
  - 10-100x faster than compute speeds
  - moving data becomes dominant
- POSIX IO does not scale
  - 45 years ago: 100MB of data at high end
  - Now: up to 1 billion times more data
  - Middleware tries to make up for limitations
- Performance price of POSIX IO is high
  - Workload-specific interposition layers:
    almost 1,000 x speed-up
- Middleware and Interposition layers
  - Either not fully exploit storage architecture, or
  - Statically encode workload-architecture mapping
  - Parallel to early database history

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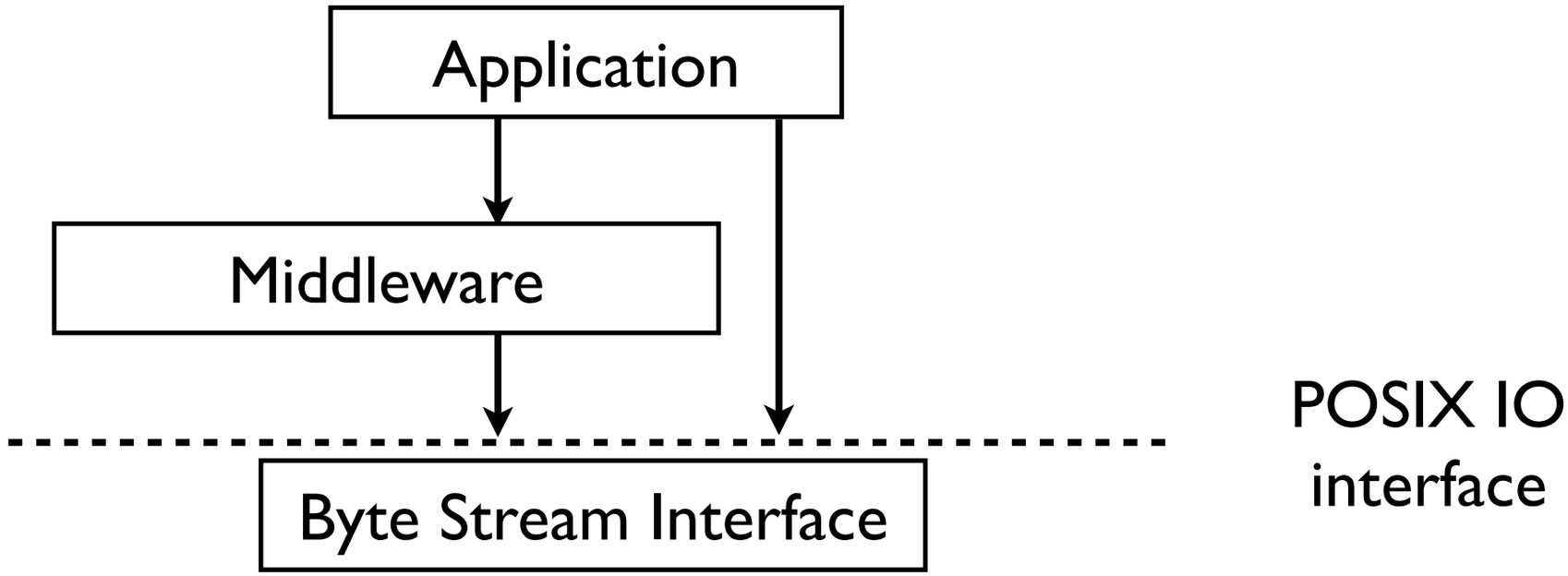
Damasc


Application
Middleware
Byte Stream Interface
POSIX IO
interface

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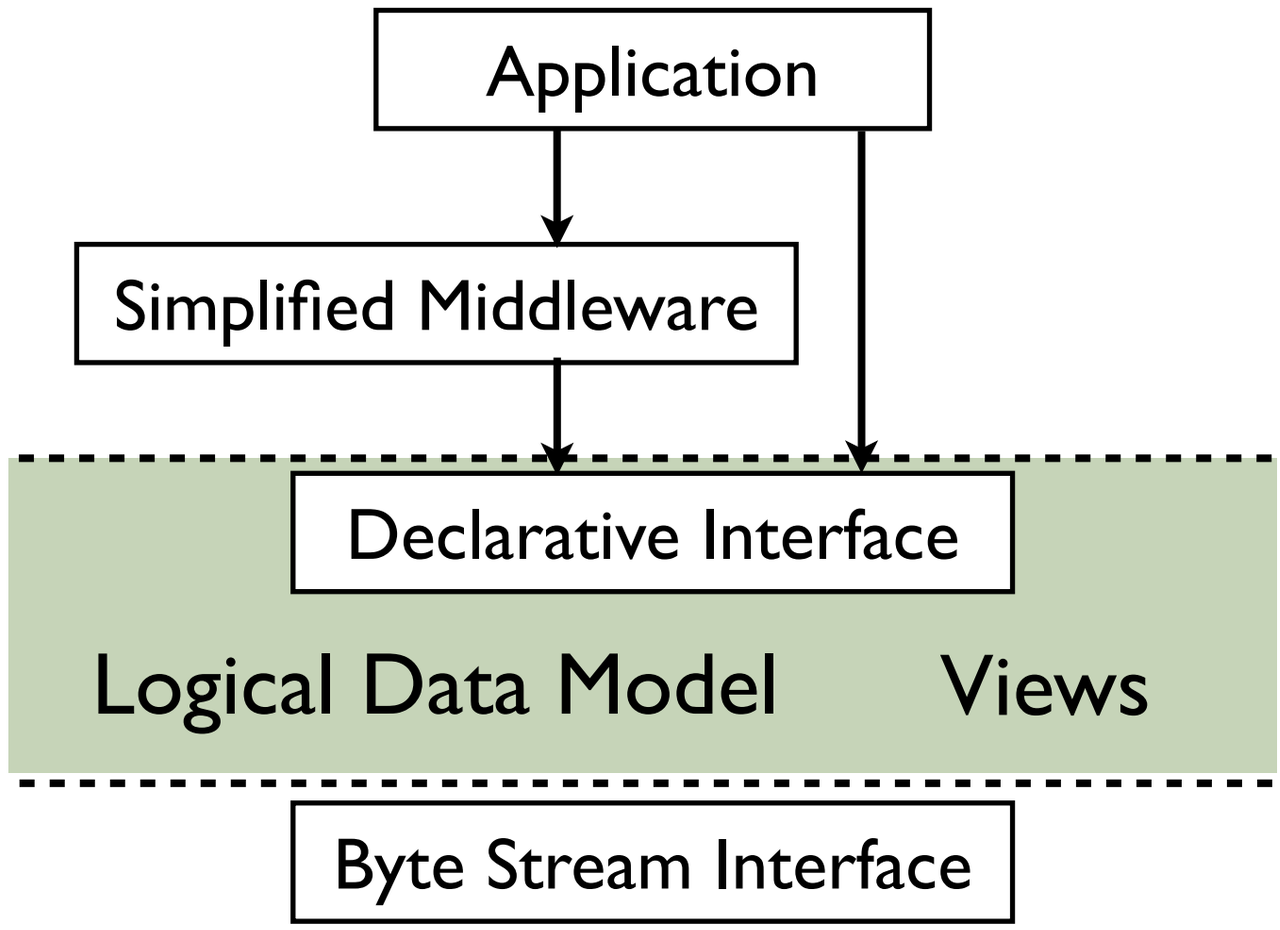
Damasc



Damasc interface

POSIX IO interface

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Why now?

1. Mature HPC Middleware APIs:
   - NetCDF, HDF5, MPI IO, ...
   - Established abstractions above POSIX IO
2. Big data increasingly forces out-of-core data management
3. Advances in auto-tuning of database systems
4. Advances in end-to-end performance management
   - Scheduling of competing data management activities
5. Advances in parallel file system scalability
   - via greater intelligence at storage nodes

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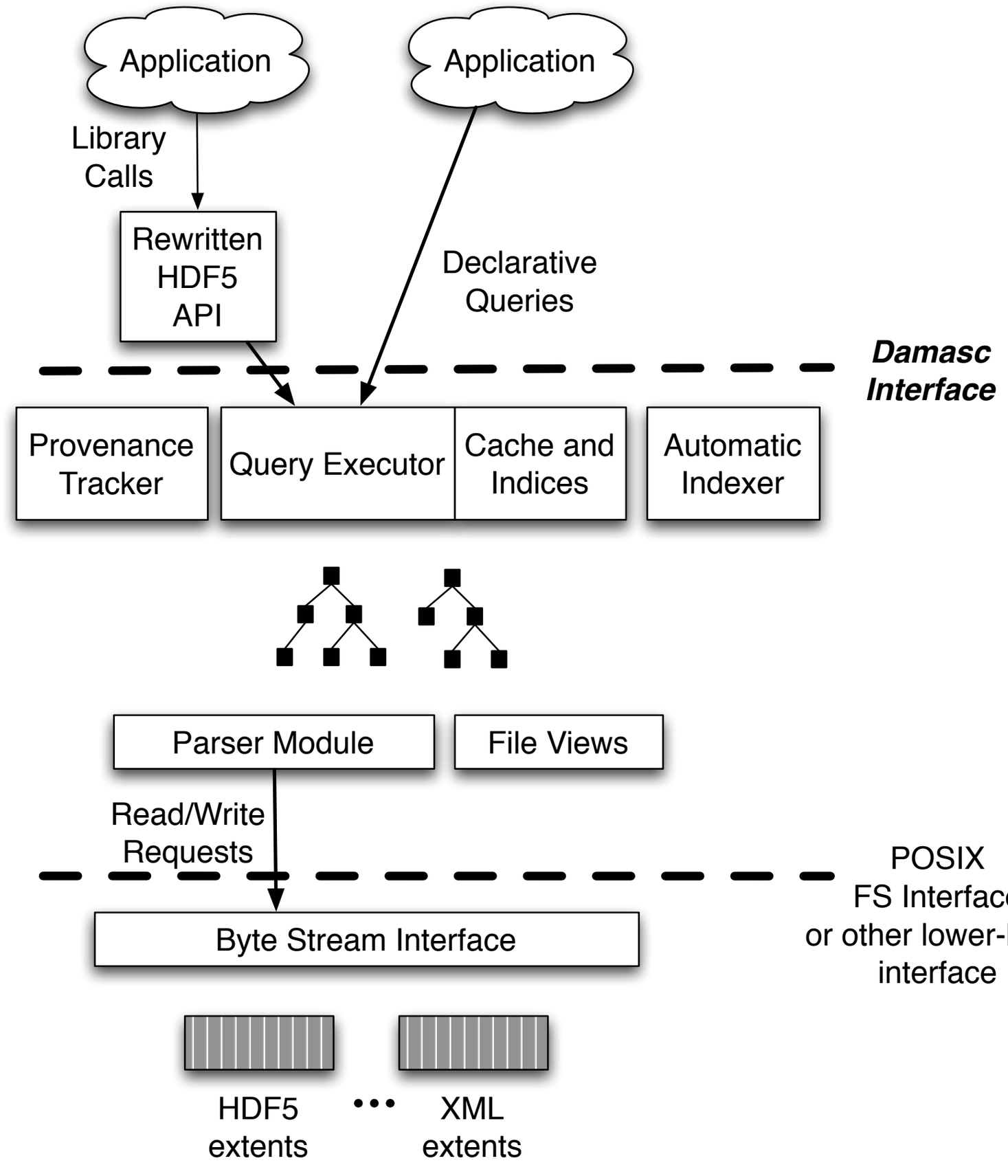
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Declarative
Queries
Damasc
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Provenance
Tracker
Query Executor
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Automatic
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Parser Module
File Views
Read/Write
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or other lower-level
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Byte Stream Interface
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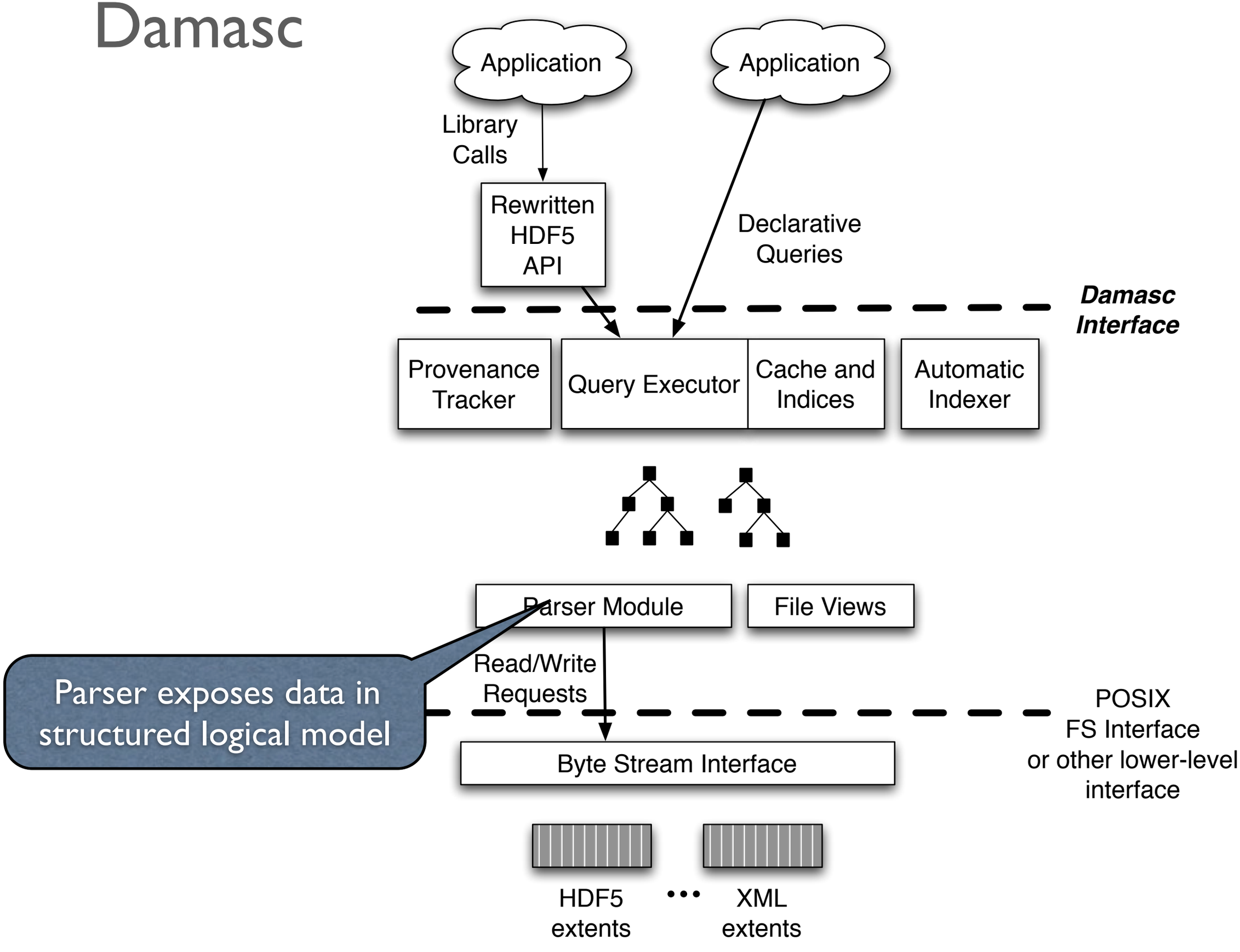
6

Damasc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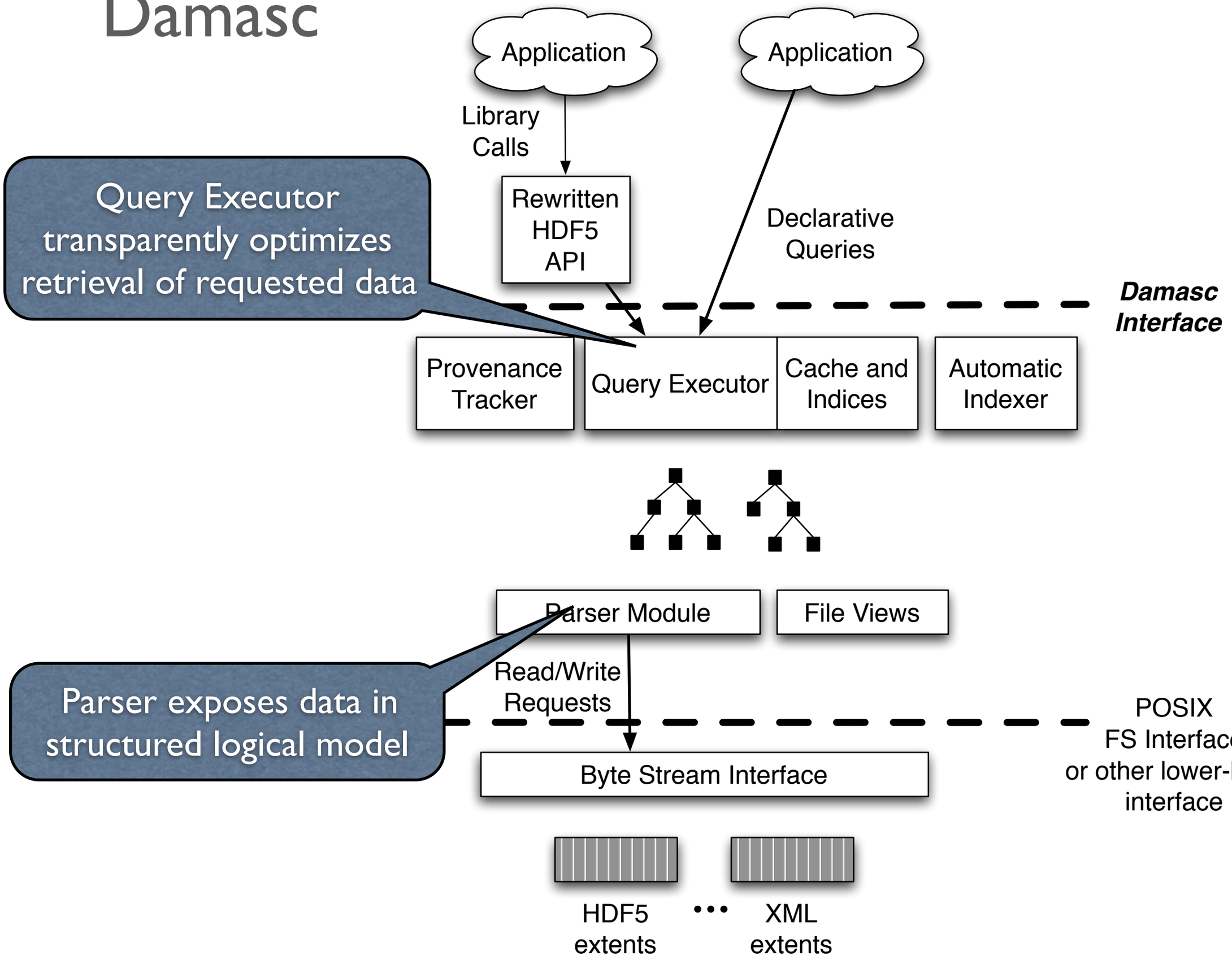
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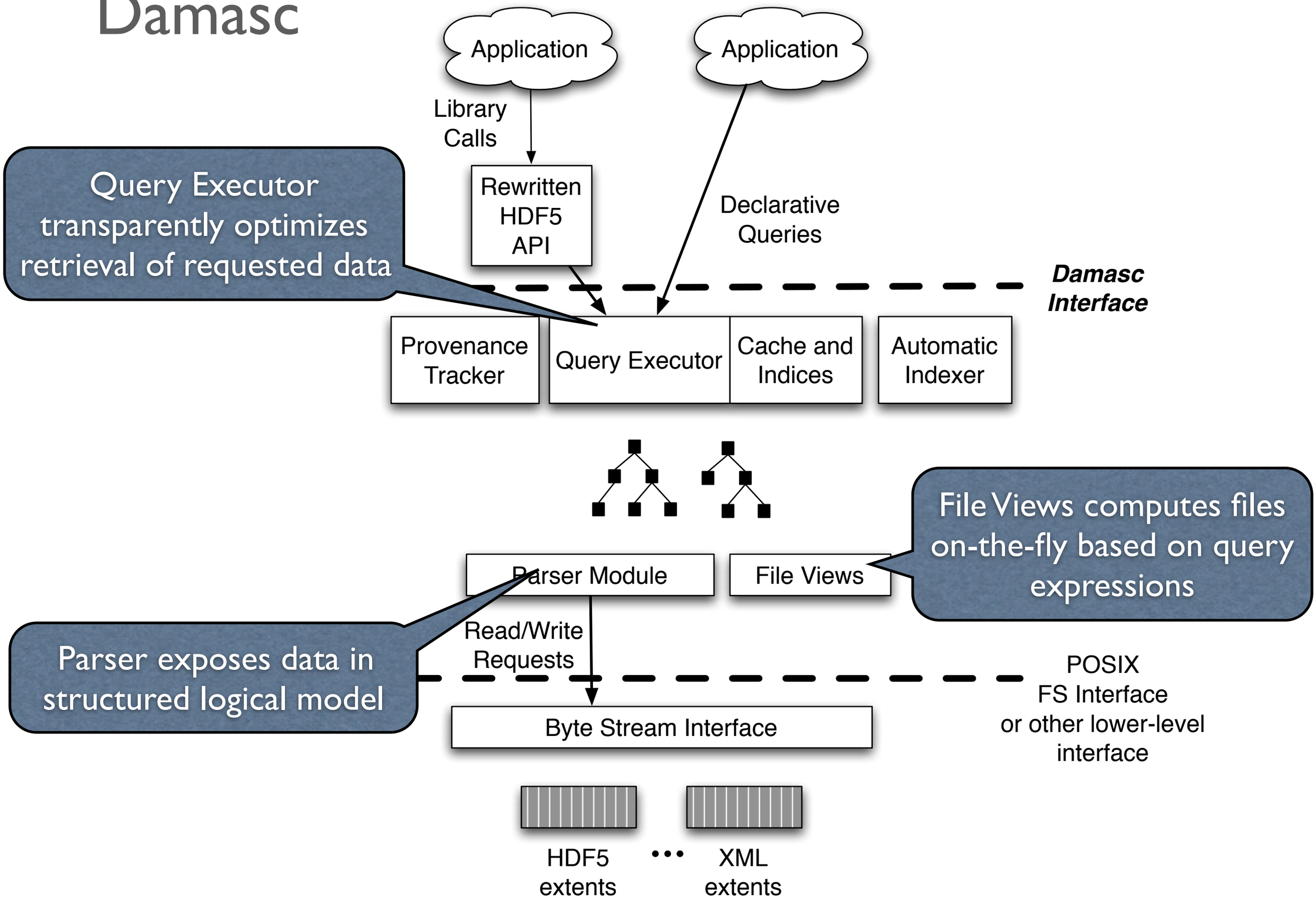
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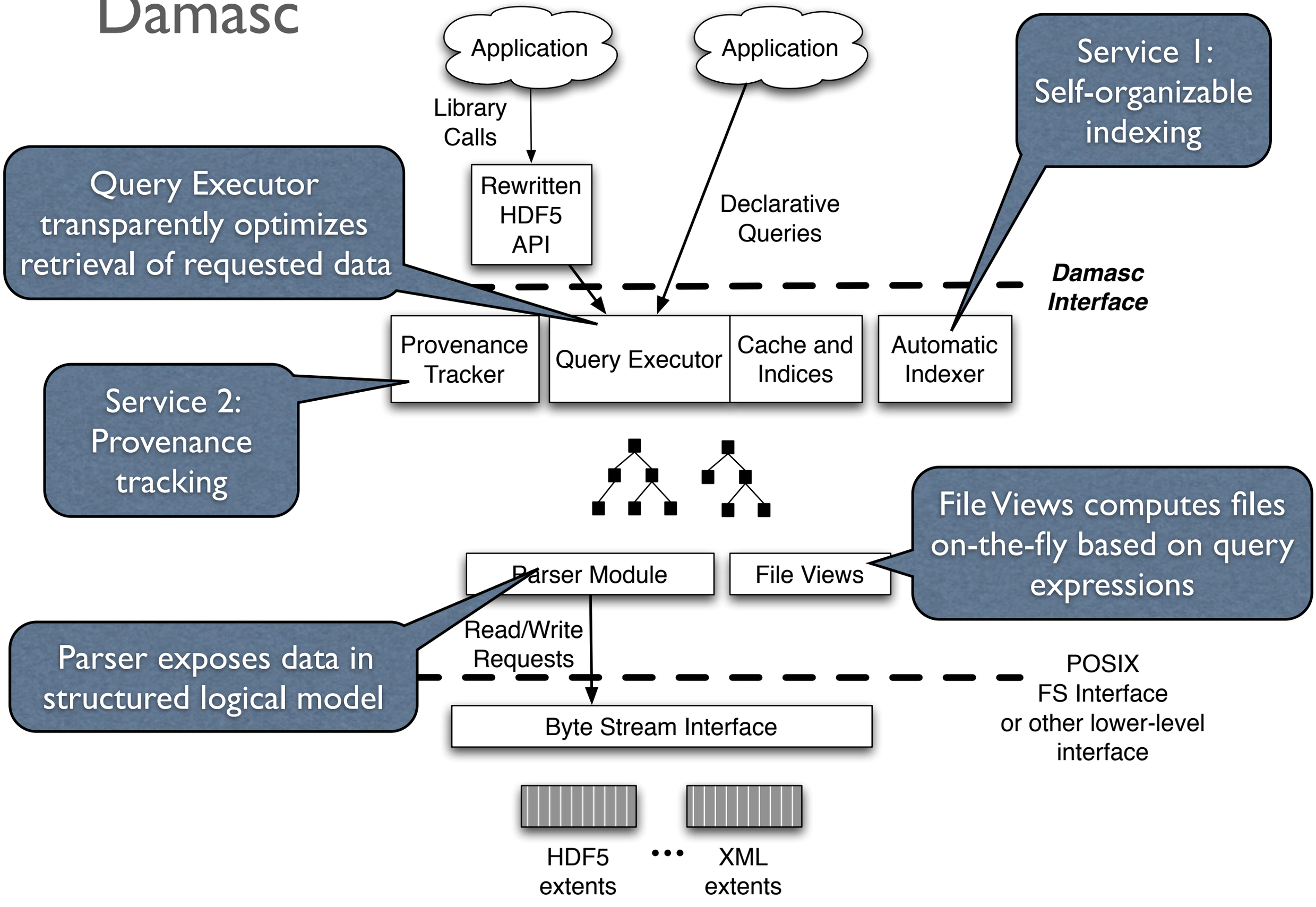
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Service 1: Self-organizable indexing
Query Executor transparently optimizes retrieval of requested data
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Query Executor
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Service 2: Provenance tracking
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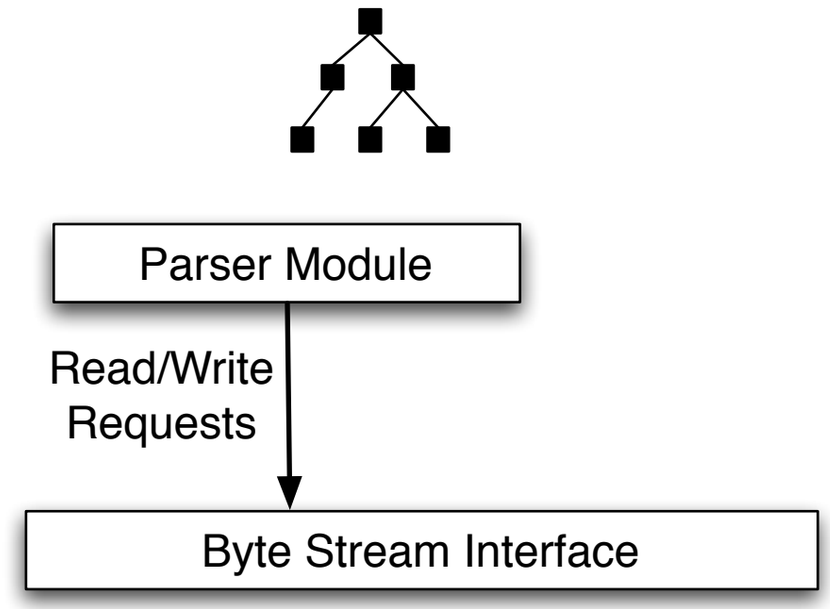
Parser Module



- Repository of format-specific parsers
- Parser creates trees
- Common semi-structured data model
  - Same abstract interface to different formats
  - Structural indices into byte stream files
- Formulation vs Evaluation of queries:
  - Formulation: based on semi-structured data model
  - Evaluation: lazy, parsing of entire file **not** required
- Optimized/scalable evaluation mechanisms ...

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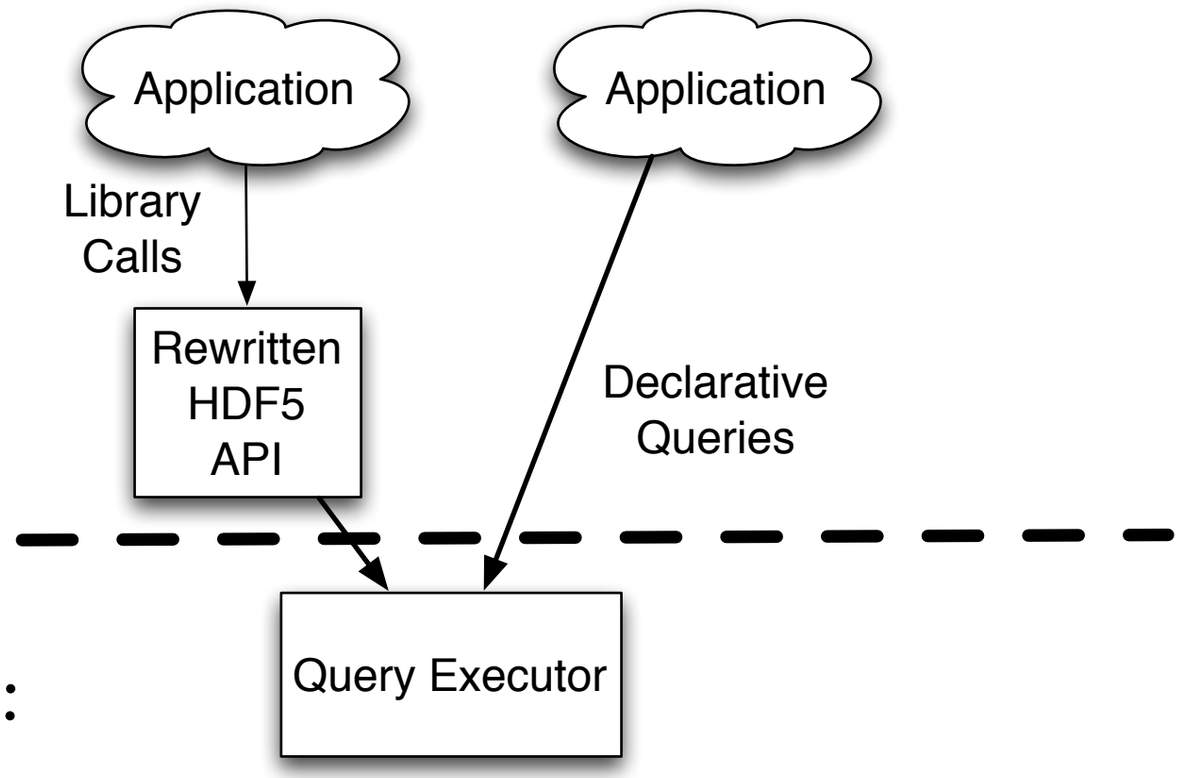
Declarative Queries



- Declarative "query" expression:
  - **What** to retrieve or update, not **how**
  - As opposed to procedural querying
- Algebraic operators:
  - Input and output is in semi-structured data model
  - Leverage existing query languages (XPath, ...)
  - Include operators of common formats (HDF5, NetCDF, ...)
- Complex expressions:
  - Retrieve/update combinations

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Declarative Access: Example

- Path access operator applied on a bib file with

  publication[/title contains ‘file’ ‘systems’]/abstract

  - Return abstracts of publications that contain the word “file” or “system” in the title

- Update operator applied on bib file with

  publication[/title contains ‘file’]/tags = ‘file’

  - Tag publications with “file” that contain the word “file” in the title

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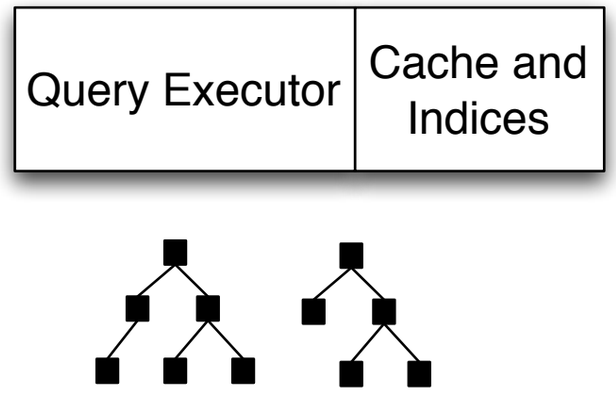
Query Optimization



- Query Executor:
  - Input: expression of logical operators
  - Output: best query plan using physical operators
  - Via: rewrite rules, cost model
- Cost Model: accounts for layout and statistics about data
- Fragmented Parsing:
  - Physical operators use file metadata to parse only what is needed
- Indexing of Keywords and File Structure
- Hybrid expressions: logical and physical operations
  - Trying to avoid need to bypass Damasc

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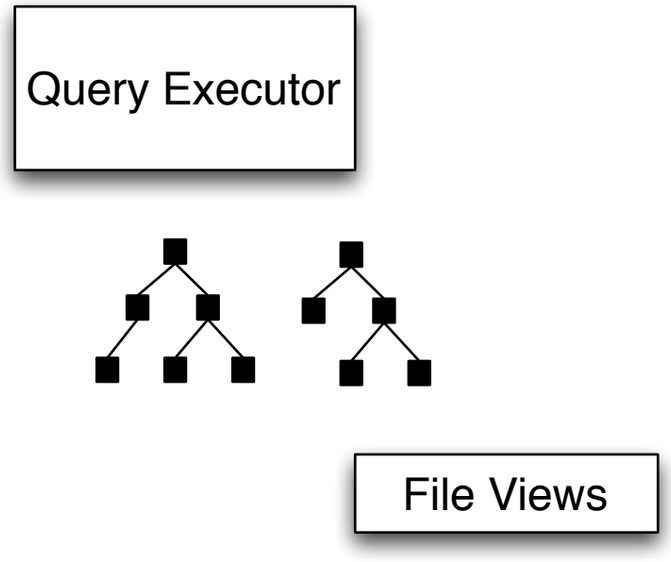
Views



- On-the-fly computation of file(s)
- First class citizen:
  - Views can be queried and/or updated
  - Views can be based on other views
- Query "fusing":
  - Optimize query against view + query defining view
- Logical Independence:
  - Views shield applications from physical format changes

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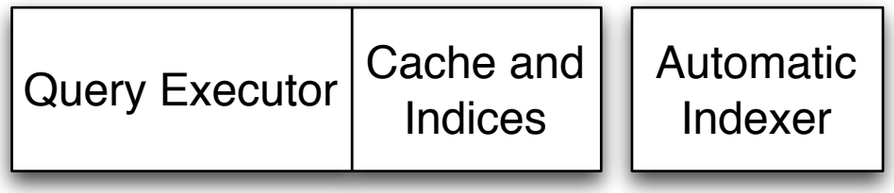
Service 1: Self-Organizable Indexing



- Index Cost vs Benefit:
  - Essential for performance
  - Cost of index maintenance
- Automatic index creation and destruction:
  - Based on recent query patterns
  - Based on index interactions
- Hybrid, partial indexing: e.g. one file has
  - inverted-list index for keywords in titles
  - path index
  - some lazy indexing

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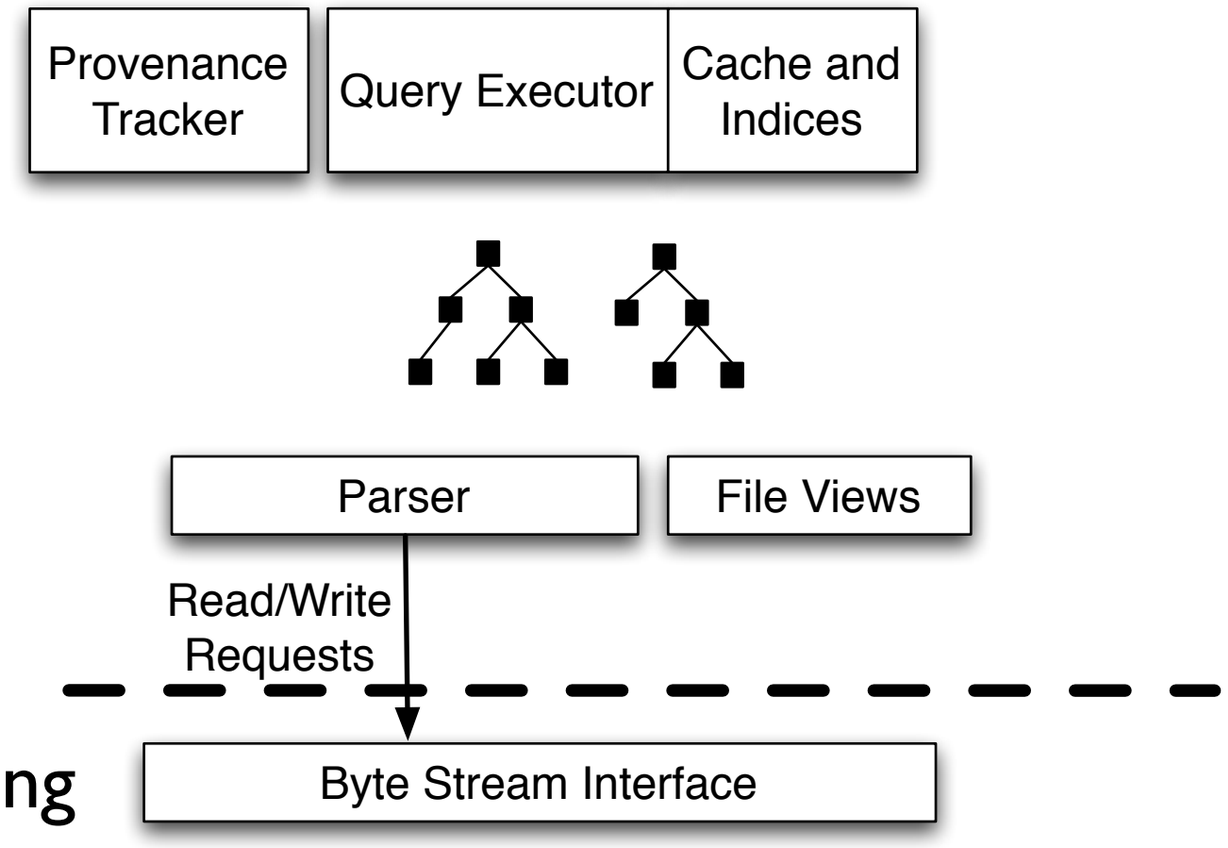
Service 2: Provenance Tracking



- End-to-end provenance tracking
  - From views to underlying files, and
  - back to (other) views
  - semantic objects (e.g. matrix)
- Automatic bridging of observed and disclosed provenance collection
  - Observed provenance collection on physical level
  - Disclosed provenance by applications on logical level

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Realization in a Parallel File System

- 1st step: middleware
  - All global Damasc data structures shared via POSIX IO
  - Limited data movement savings
- 2nd step: Ceph extension
  - Distributed query executor, parser, indexer
  - Damasc spans storage clients and servers
  - Leveraging Ceph's intelligent OSDs
- Format-aligned striping
  - Striping strategy based on structure, not bytes
  - Adaptive mapping to distributed data structures
  - Leveraging Ceph's scalable metadata cluster

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Applications & Damasc

- Applications rely on higher-level APIs:
  - NetCDF, HDF-5, ...
- Declarative Damasc interface
  - Simplification for middleware libraries
  - Cross-workload-adaptive optimization of the storage of particular data sets w/ multiple formats
- Views for overcoming bottlenecks
  - Example: View mapping one file to many files plus automatic indexing (similar to PLFS)

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Conclusions

- Moving data becomes dominant overhead
- Middleware provides much-needed functionality but not performance
- Damasc adds data management layer to FS
  - Additional semantic information for storage layer
  - Facilitate in-place processing on storage nodes
  - Eventually: full-scale distributed processing

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Thank you

- Questions and comments?

- Contact: carlosm@cs.ucsc.edu

- Please read our paper!

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