HSDS:

A REST Service for HDF5

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Overview

- Why a HDF Service?
- What's REST?
- HSDS features
- Architecture
- Security
- Demo

Also…

This talk will focus on the service, but if you missed yesterday's talk on h5pyd (Python client library for HSDS), it should be available as a video soon.

And tomorrow I'll be talking about the REST VOL (C client for HSDS)

Introducing HSDS

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HSDS – Highly Scalable Data Service -- is a REST-based web service for HDF data

Design criteria:

- Performant – good to great performance
- Scalable – Run across multiple cores and/or clusters
- Feature complete – Support (most) of the features provided by the HDF5 library
- Utilize POSIX or object storage (e.g. AWS S3, Azure Blob Storage)

Note: HSDS was originally developed as a NASA ACCESS 2015 project: https://earthdata.nasa.gov/esds/competitive-programs/access/hsds

HSDS Platforms

HSDS is implemented as a set of containers and can be run on common container management systems:

docker | kubernetes | Amazon EKS | Azure Kubernetes Service (AKS) | DC/OS

Using different supported storage systems:

POSIX Filesystem | amazon web services S3 | Microsoft Azure Blob Storage | OpenIO | ceph

HSDS Features

- **HDF5 Feature Support**
  - Groups, Links (including multi-link), Attributes, Datasets, Committed Datatypes
  - Simple and Compound datatypes
  - Hyperslab and Point Selections (also SQL-style queries)
  - Support for compression
    - Standard HDF5 shuffle and deflate filters
    - Support for BLOSC compressors

- **Container based**
  - Run in Docker or Kubernetes or DC/OS

- **Scalable performance**:
  - Can cache recently accessed data in RAM
  - Can parallelize requests across multiple nodes
  - More nodes ➔ better performance
  - Cluster based – any number of machines can be used to constitute the server
  - Multiple clients can read/write to same data source
  - No limit to the amount of data that can be stored by the service

Why an HDF Service?

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Before talking about HSDS, let's ask why a service might be a handy thing to have.
Some reasons why this might be of interest…

- Allow remote access to large datasets (the inertia of big data)
- Provide language-neutral interface to HDF
- Enable web-based applications
- Facilitate container-based applications (Docker, Kubernetes, Mesos)
- Explore alternative implementations of HDF – object-storage, asyncio, non-MPI parallelism, etc.

What is REST?

- REST is a (loose) standard for creating web-based APIs
- Typically built on top of HTTP
- Uses the 4 most common HTTP operations: GET, POST, PUT, DELETE
- Stateless – one operation doesn't depend on another
- URI based – every object has a unique identifier
- Language Neutral

The HDF REST API

- The HDF REST API is a specification for a web API that enables the HDF data model
- Used by HSDS (and also h5serv – an earlier prototype)
- Other implementations are free to adopt it as well

A simple diagram of the HDF REST API

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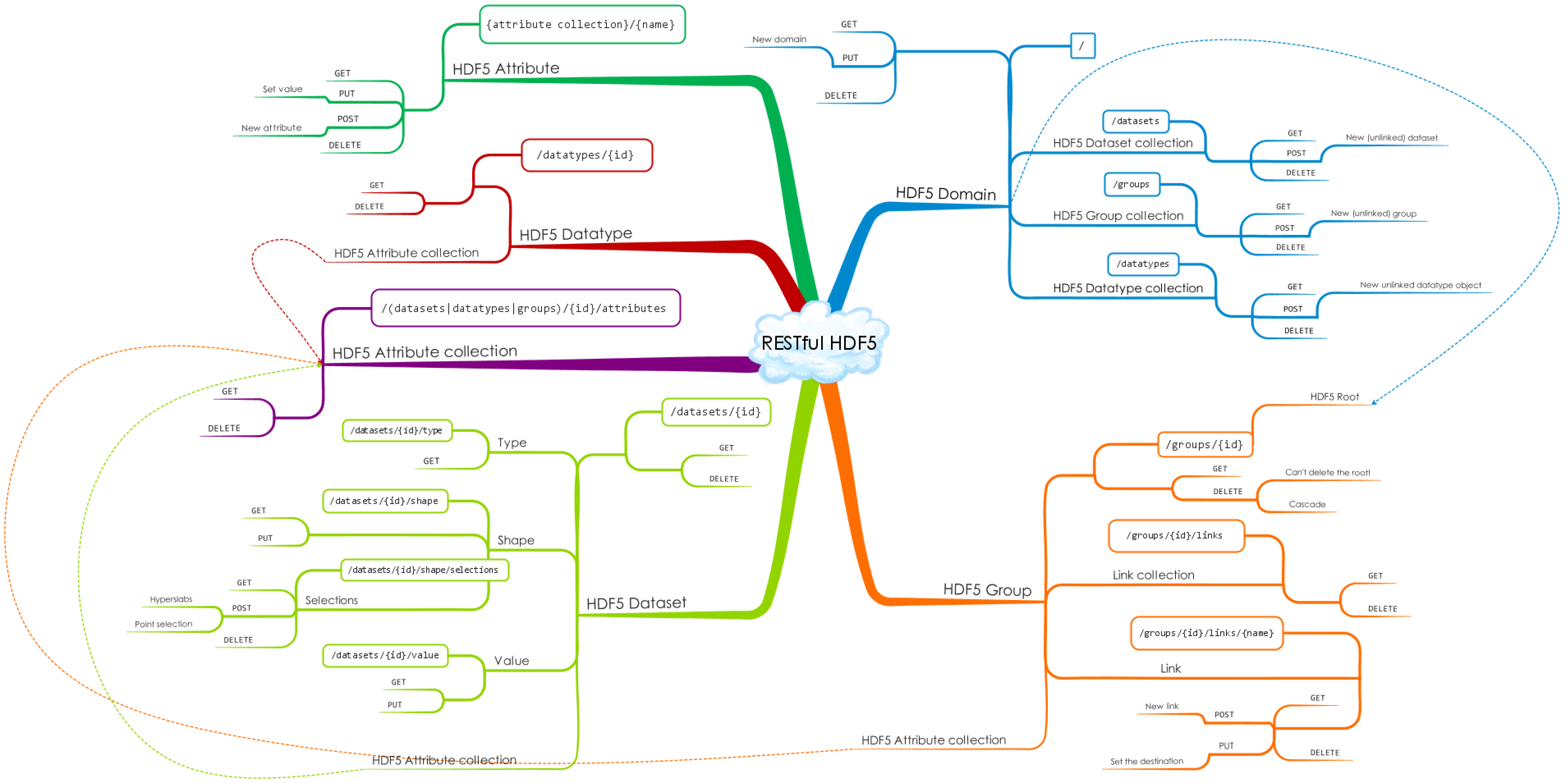


What makes it RESTful?

- Client-server model
- Stateless – (no client context stored on server)
- Cacheable – clients can cache responses
- Resources identified by URIs (datasets, groups, attributes, etc)
- Standard HTTP methods and behaviors:

Method	Safe	Idempotent	Description
GET	Y	Y	Get a description of a resource
POST	N	N	Create a new resource
PUT	N	Y	Create a new named resource
DELETE	N	Y	Delete a resource

Example URI

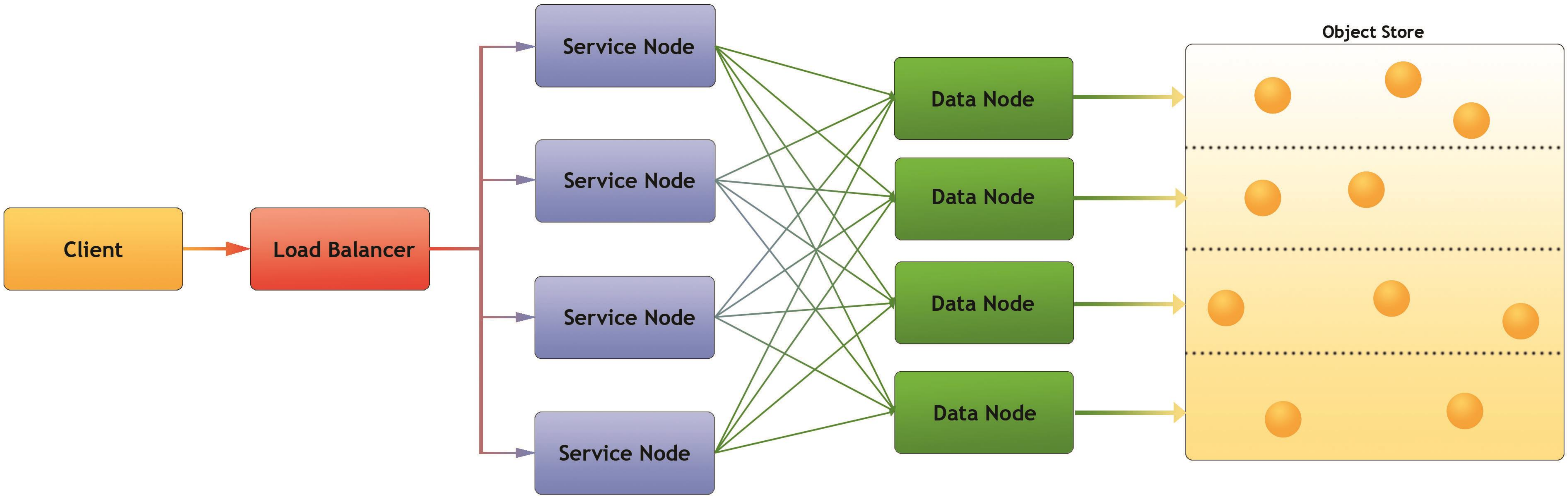
scheme	domain	port	resource	Query param
`http://`	`kitalabhsds.hdfgroup.org`	`:7253`	`/datasets/34…d5e/value`	`?select=[0:4,0:4]`

- Scheme: the connection protocol
- Endpoint: DNS name for the server (could be a load balancer)
- Port: the port the server is running on
- Resource: identifier for the resource (dataset values in this case)
- Query param: Modify how the data will be returned
  - (e.g. hyperslab selection)

Request response can either be:

- JSON – for metadata
- Binary – for dataset reads

HSDS Architecture



- Client: Any user of the service
- Load balancer – distributes requests to Service nodes
- Service Nodes – processes requests from clients (with help from Data Nodes)
- Data Nodes – responsible for partition of Object Store
- Object Store: Base storage service (e.g. AWS S3)

HDF Sharded Schema

Big Idea: Map individual HDF5 objects (datasets, groups, chunks) as Object Storage Objects

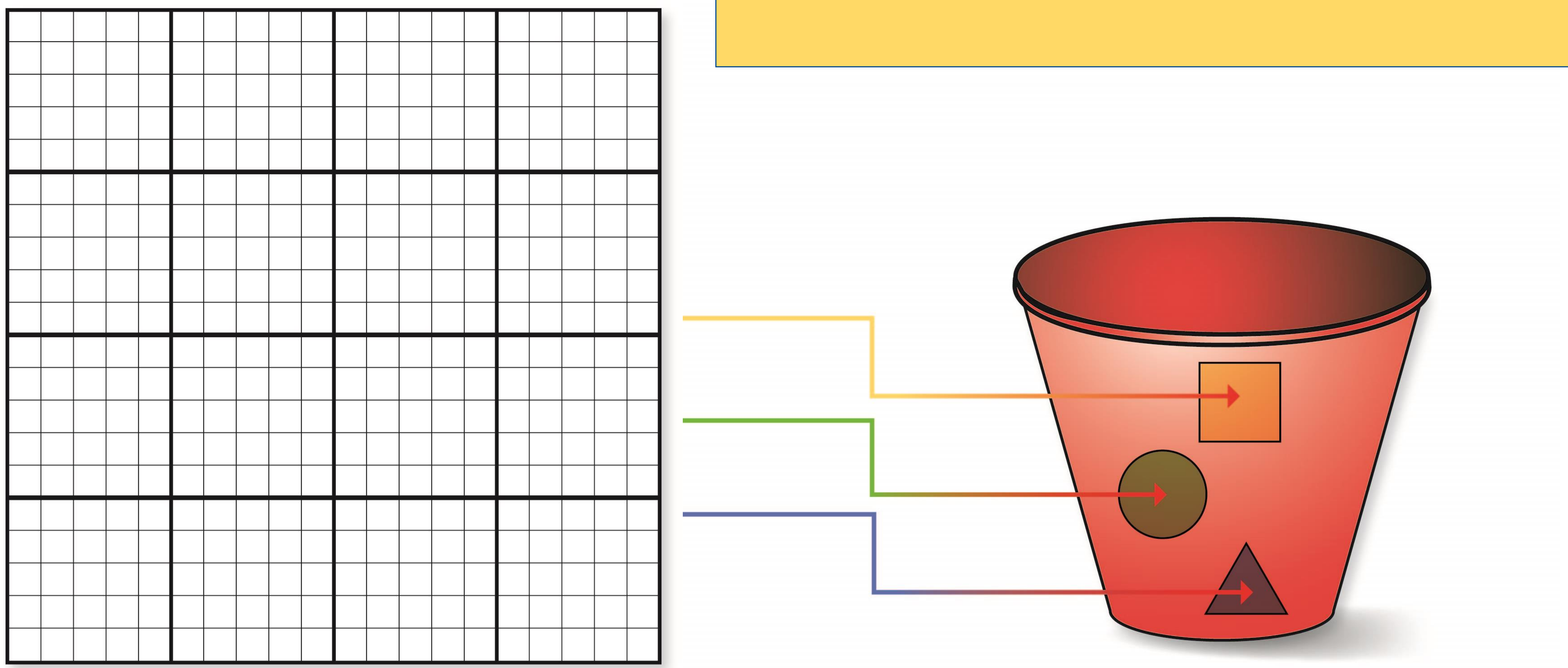
Why a sharded data format?

- Limit maximum size of any object
- Support parallelism for read/write
- Only data that is modified needs to be updated
- Multiple clients can be reading/updating the same “file”
- Don’t need to manage free space

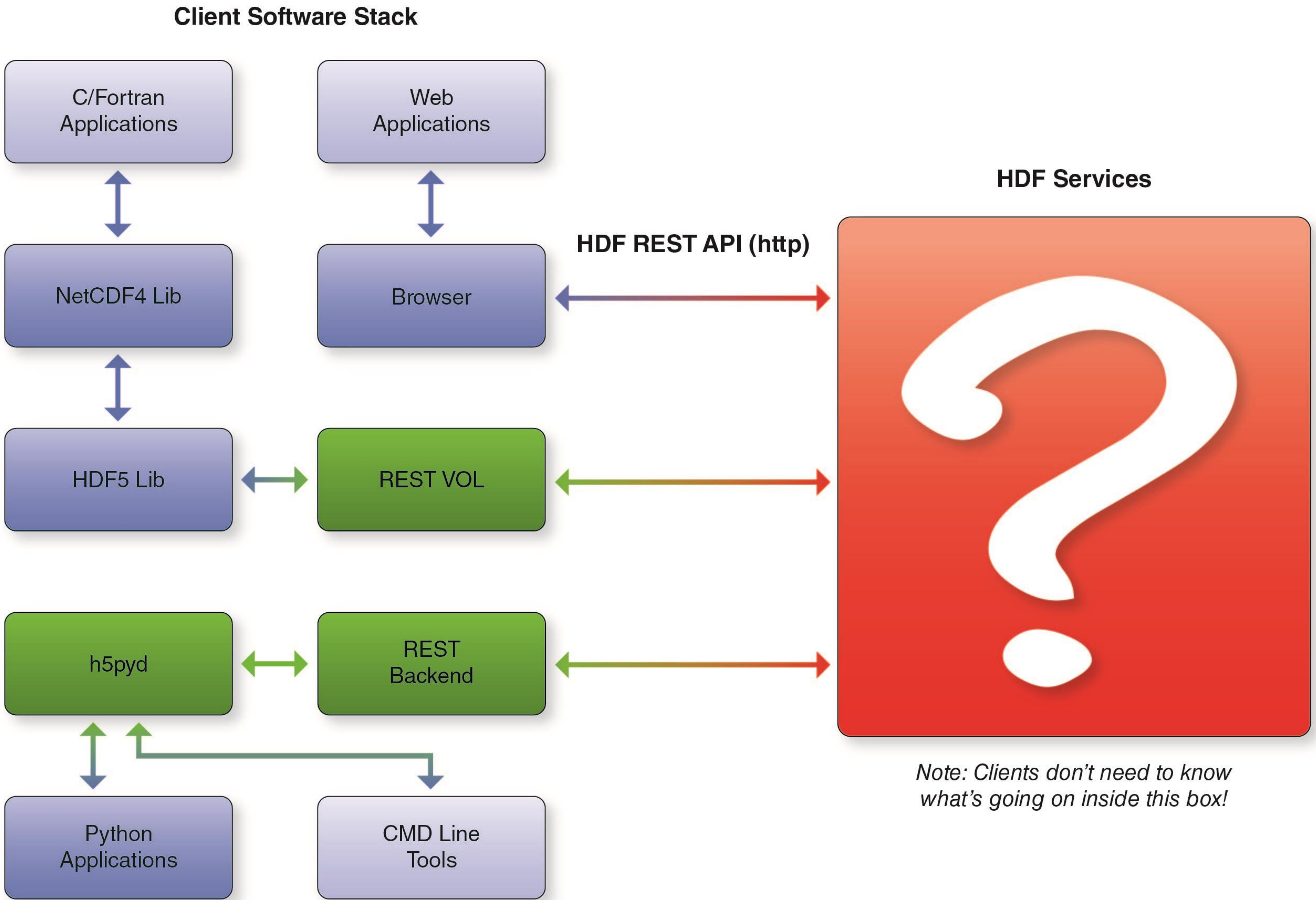
Legend:

- *Dataset is partitioned into chunks*
- *Each chunk stored as an object (file)*
- *Dataset meta data (type, shape, attributes, etc.) stored in a separate object (as JSON text)*

Each chunk (heavy outlines) get persisted as a separate object



Client-side support



A word about Python…

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HSDS is implemented in Python which is not thought of as a high performance language. In practice though it's worked out quite well based on the following factors:

- HSDS utilizes Python packages (e.g. BLOSC, NumPy) that are wrappers around optimized C (Fortran?) code
- HSDS uses Numba (basically a just-in-time compiler for Python) to speed up critical code blocks
- Heavy use of asyncio (see next two slides) makes efficient use of CPU for IO based workloads

Python async in HSDS

- HSDS relies heavily on Python's new asyncio module
  - Concurrency based on *tasks* (rather than say multithreading or multiprocessing)
  - Task switching occurs when process would otherwise wait on I/O

Example:

```
async def my_func():
    a_regular_function_call()
    await a_blocking_call()
```

- Control will switch to another task when await is encountered
- Result is the app can do other useful work vs. blocking
- Supporting 1000's of concurrent tasks within a process is quite feasible

Parallelizing data access with asyncio

- SN node invoking parallel requests on DN nodes

```
tasks = []
for chunk_id in my_chunk_list:
    task = asyncio.ensure_future(read_chunk_query(chunk_id))
    tasks.append(task)
await asyncio.gather(*tasks, loop=loop)
```

- Read_chunk_query makes a http request to a specific DN node
- Set of DN nodes can be reading from S3, decompression and selecting requested data in parallel
- Asyncio.gather waits for all tasks to complete before continuing
- Meanwhile, new requests can be processed by SN node

Security – authentication and authorization

In a web service it's important to verify who's who (authentication) and only allow permitted actions (authorization

- Authentication - HSDS supports several authentication protocols:
  - HTTP Basic Auth
  - Azure Active Directory – (OAuth 2.0)
  - Google OpenID (also Oauth 2.0)
- Authorization – Access Control Lists (ACLs)
  - Per domain list of which users can perform which actions (read, update, delete, etc)
  - Role Base Access Control (RBAC) – enable permission based on user groups

Questions?

Try it out!

Get the software here:

- HSDS: https://github.com/HDFGroup/hsds
- H5pyd: https://github.com/HDFGroup/h5pyd
- REST VOL: https://github.com/HDFGroup/vol-rest
- REST API documentation: https://github.com/HDFGroup/hdf-rest-api
- Example programs: https://github.com/HDFGroup/hdflab_examples