EOS Open Storage

evolution of an ecosystem for scientific data repositories

http://eos.cern.ch

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CERN IT-ST

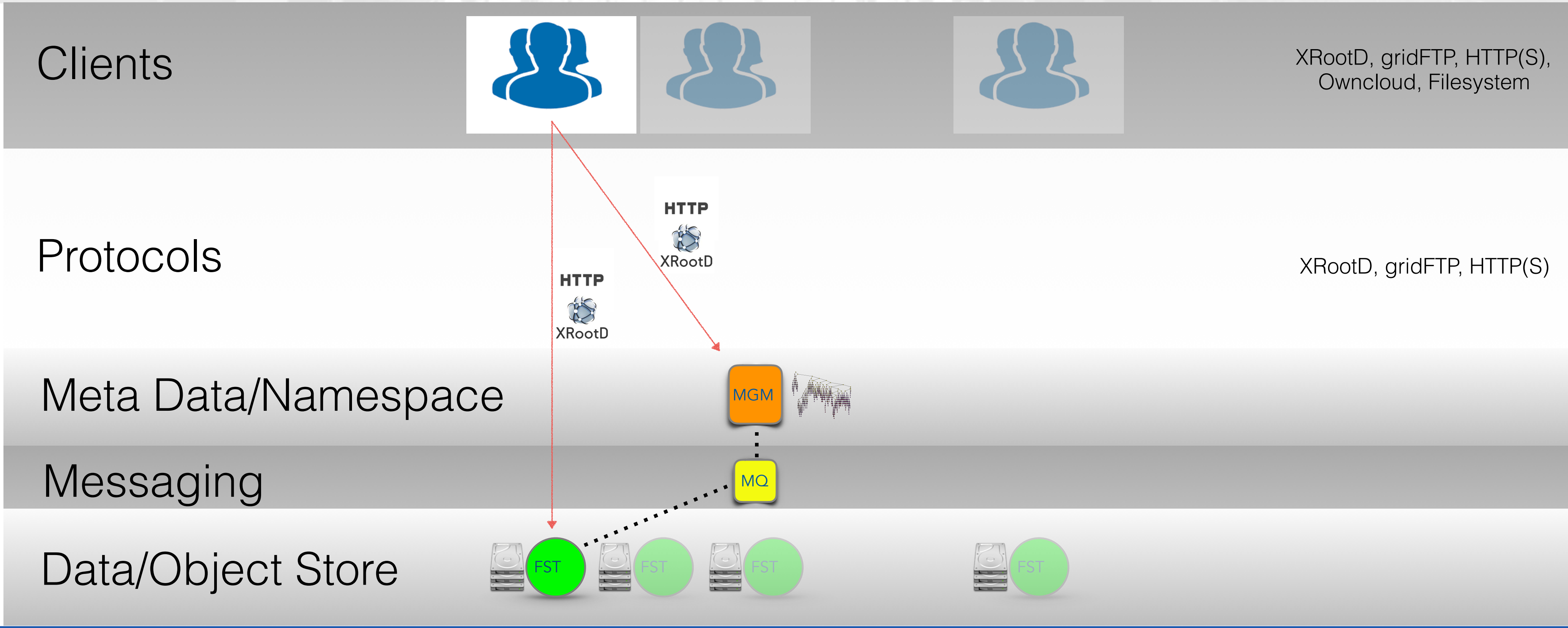
Overview

- **Introduction**
  - what is EOS?
  - history
  - architectural evolution
- EOS **service** at CERN
  - dimension & challenges
- EOS in a science **ecosystem**
  - EOS, CERNBox & SWAN
- EOS as a **filesystem**
- Evolution **data processing** - object storage models

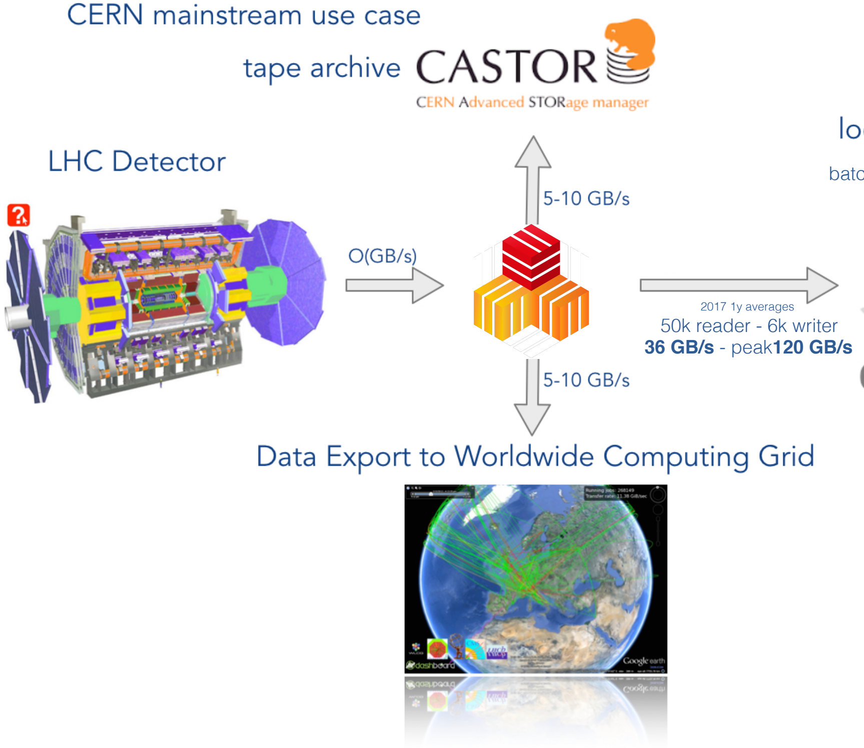
What is EOS ?

- **disk storage system** designed to serve **physics analysis** use cases
  high concurrency, pseudo-random access, LAN/WAN clients
- implemented as plug-ins into the **XRootD** framework
- native transport protocol is **XRootD** [optimized for latency compensation]
- code is written in C++ in IT-ST group at CERN

What is EOS ?


Clients
XRootD, gridFTP, HTTP(S), Owncloud, Filesystem
Protocols
HTTP
XRootD
HTTP
XRootD
XRootD, gridFTP, HTTP(S)
Meta Data/Namespace
MGM
Messaging
MQ
Data/Object Store
FST
FST
FST
FST

EOS LHC Use Case

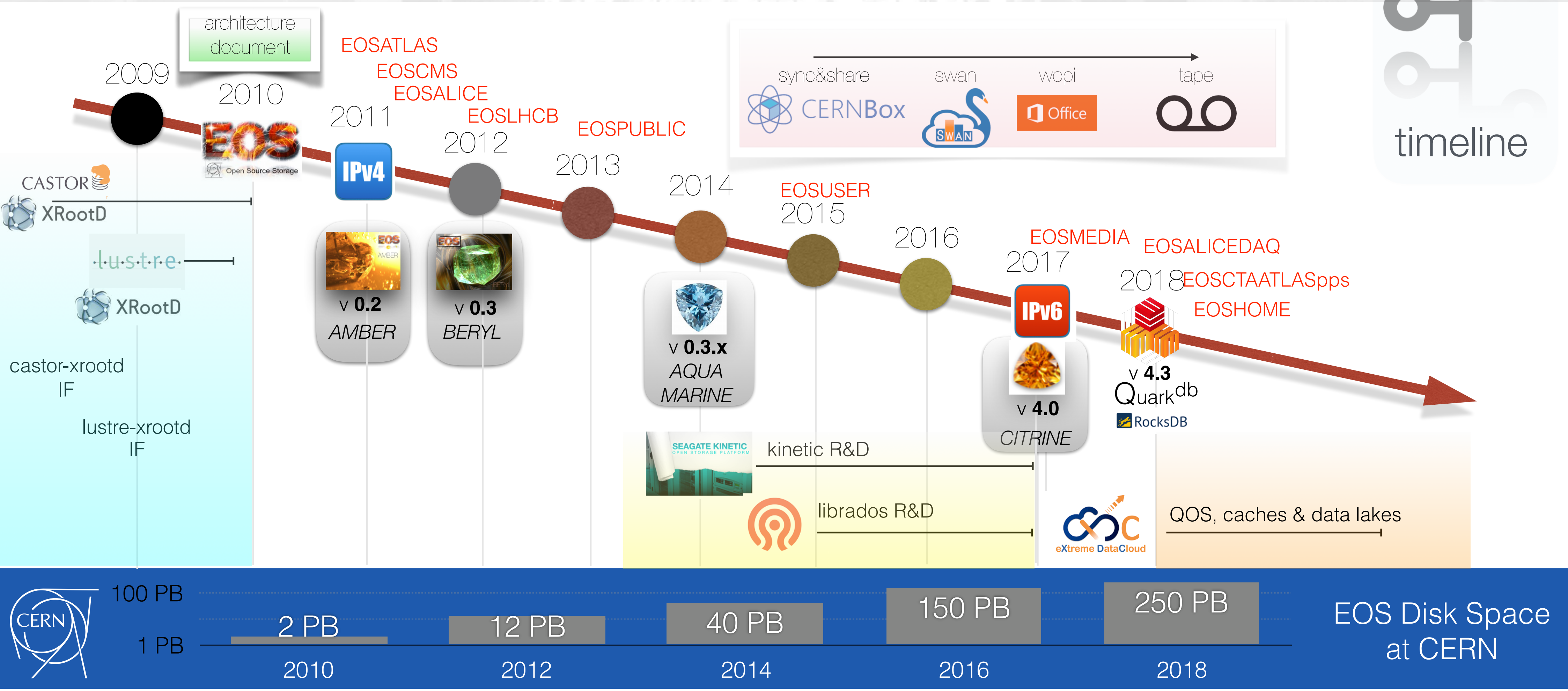


2017 1y averages
50k reader - 6k writer
36 GB/s read - peak **120 GB/s**

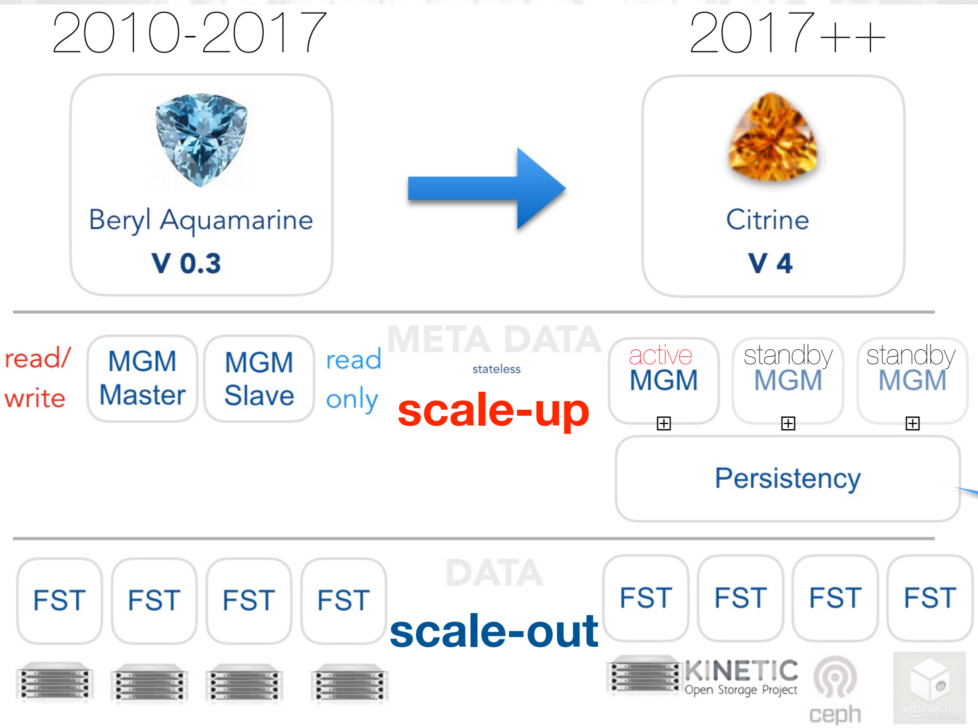
CERN

EOS

Project History



Introduction
Architectural evolution



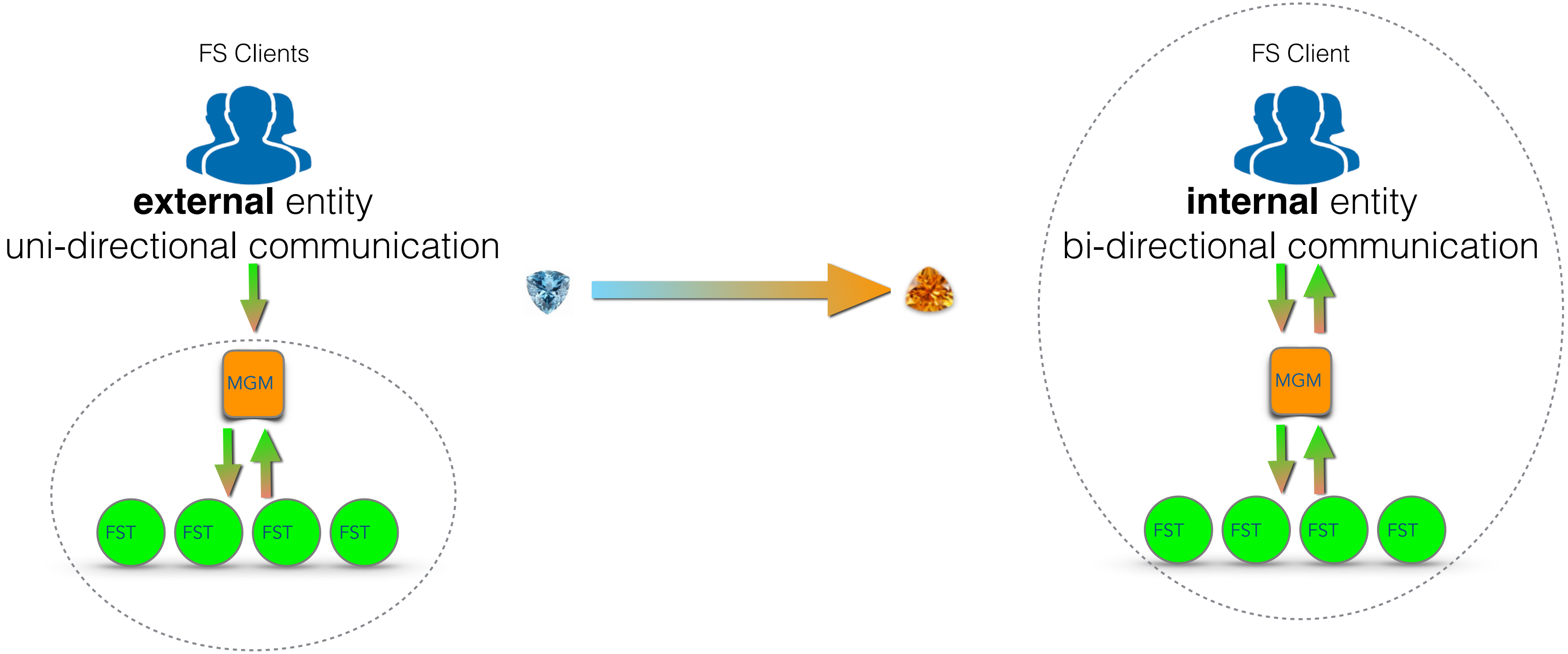
stateful in-memory

stateless + cache in-memory

Parallel Sessions
[Scaling the EOS namespace]

meta data service daemon becomes stateless

Introduction
Architectural evolution



better support of filesystem semantics requires
FS clients receiving call-backs

EOS service at CERN

designed as a 'lossy' service with two replica CERN/Wigner file replication

2017

statistics

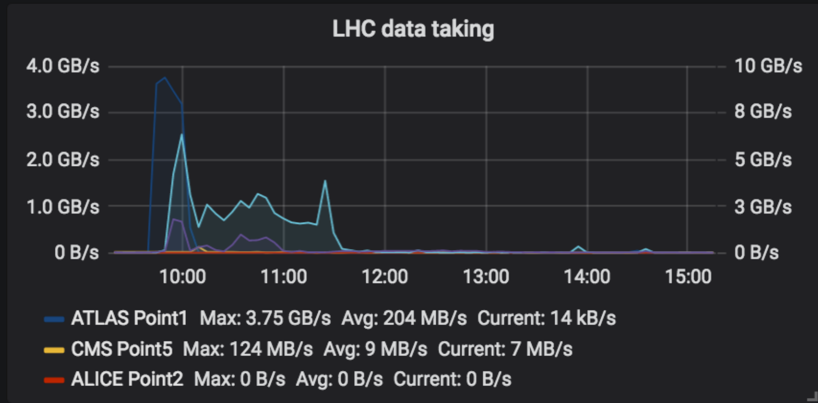
```
bytes read        1.00 EB/a
bytes written     0.25 EB/a
disk  IO          7.90 EB/a
hard disks        ~ 50k
streams           ~ 55k
fileloss rate     ~ O(10⁻⁶)/a
```

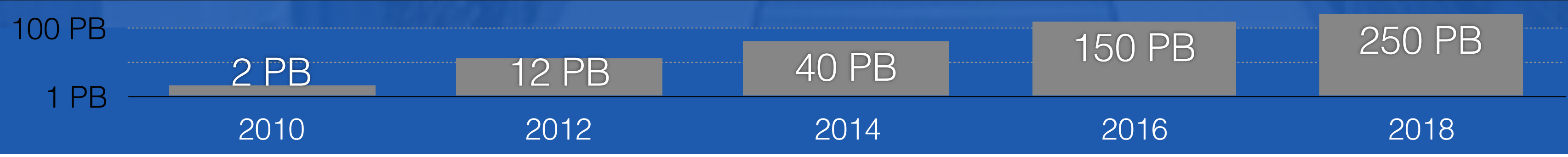
Parallel Sessions
Providing large-scale disk storage at CERN

Parallel Sessions
Disk failures in the EOS setup at CERN

Number of Files	Number of Directories	Total Space	Free Space	MGM # of open FDs
2.969 Bil	181 Mil	244 PB	66.2 PB	44775

Current Writers	Current Readers	IOPS	Write Throughput	Read Throughput
27.0 K	62.5 K	188 K	3.94 GB/s	35.2 GB/s





EOS Disk Space at CERN

EOS service at CERN

- *cheap* disk storage
- > 1.300 server, 50k disks
- JBOD with dual (geo-) replication
- 48-192 disks per standard head-node (batch server) in production
- new big server provide **2 PB** storage capacity
- **BEER** containerised batch jobs on EOS disk server
  EOS storage service daemon light-weight, allows to use 90% of free CPU resources

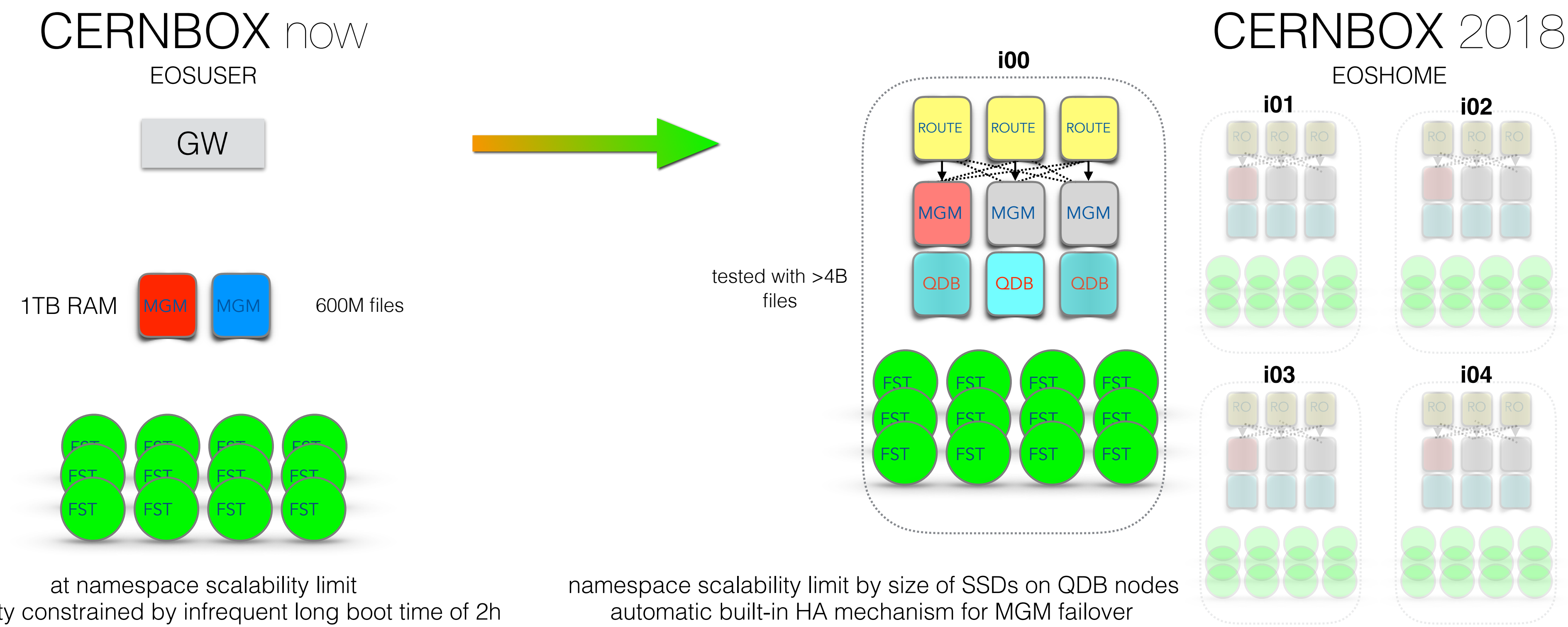
Parallel Sessions
Sharing server nodes for storage and compute

cheap volume storage on HDD

CERN

A new CERNBOX backend

Segmented high-available service model



at namespace scalability limit
availability constrained by infrequent long boot time of 2h

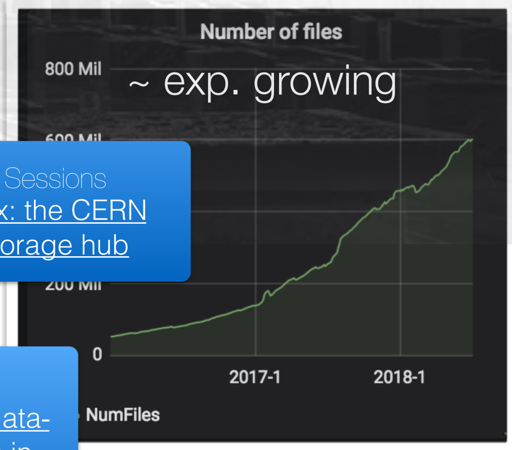
namespace scalability limit by size of SSDs on QDB nodes
automatic built-in HA mechanism for MGM failover

Since 2017 service running over scalability limit - new service architecture

2015++ EOS

CERNBox

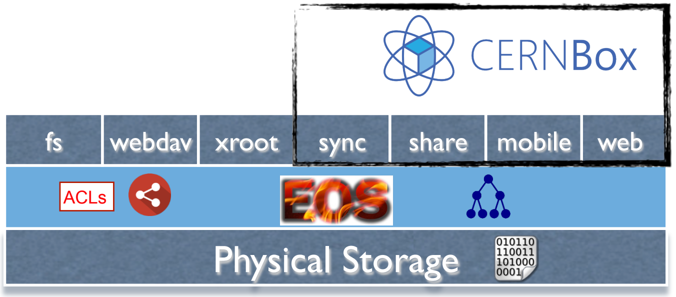
building block of an ecosystem for scientific data repositories



Parallel Sessions
CERNBox: the CERN cloud storage hub

Poster Sessions
The EU Up to University Project

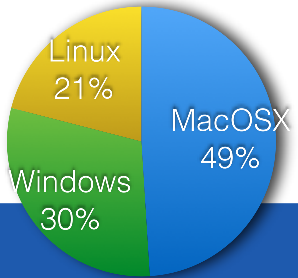
Parallel Sessions
Cloud Storage for data-intensive sciences in science and industry



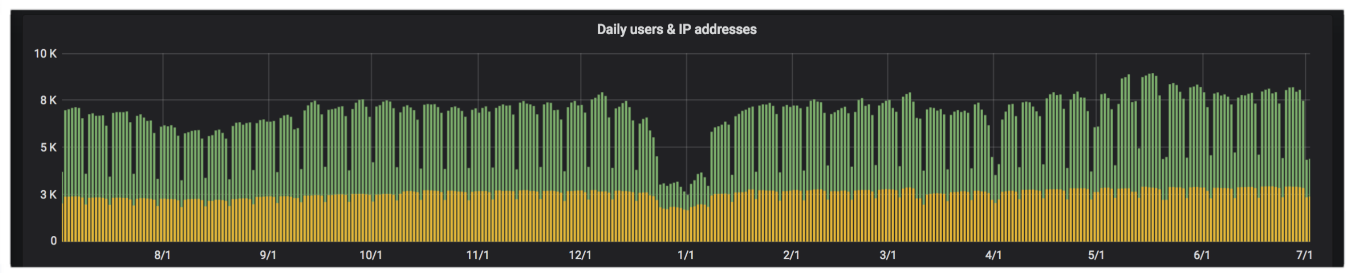
- "**dropbox**" for science
- **cloud storage**, **synchronisation** and **file sharing** service
- implemented as **web services** in front of EOS backend

Office

since mid 2017 support for collaborative editing

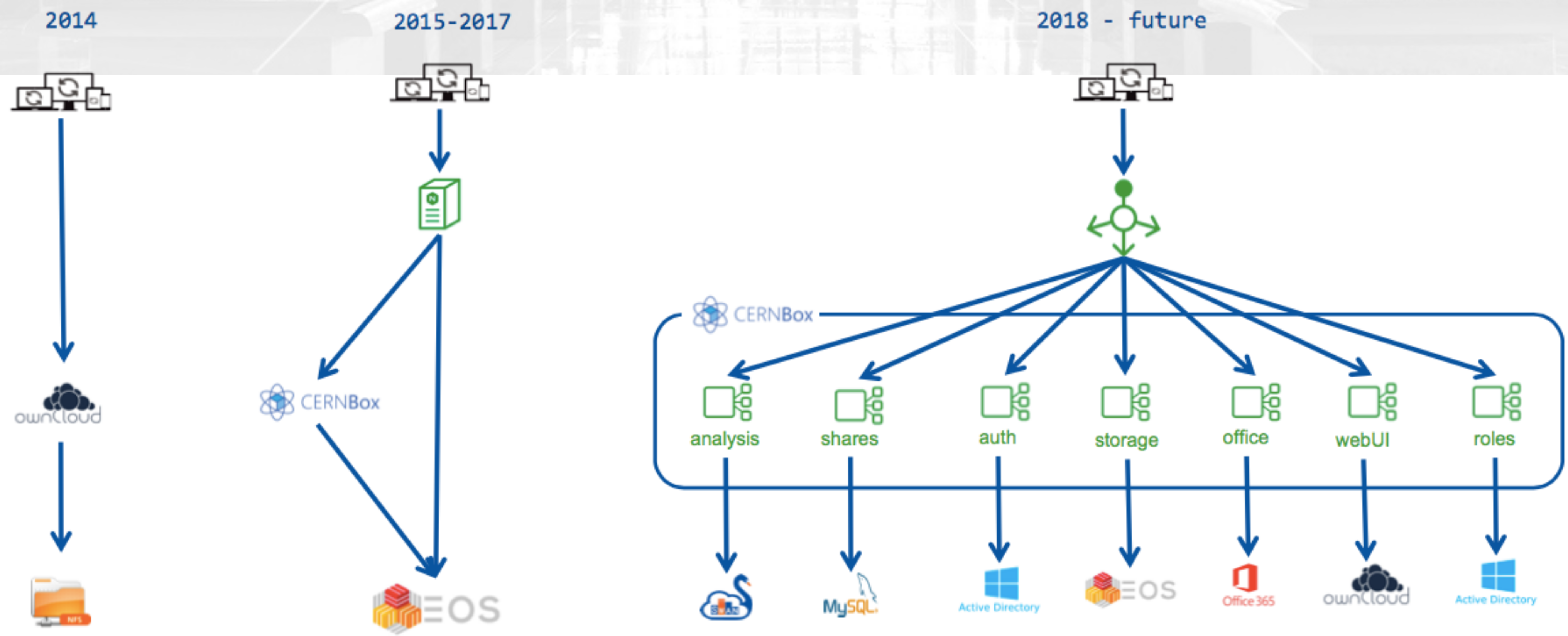


connected client platforms



~3.000 daily users, 9k connected devices

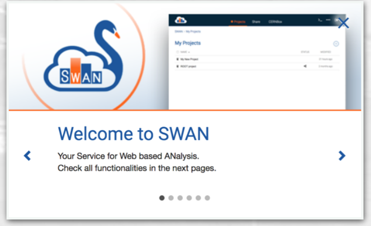
CERNBox Evolution



CERNBox refactored using micro service approach - boost performance & functionality

2016++

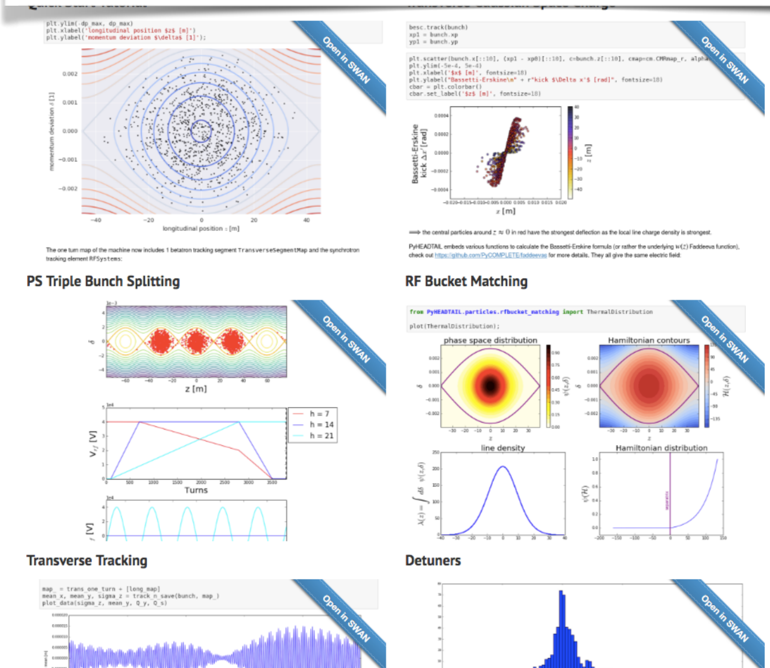
SWAN service

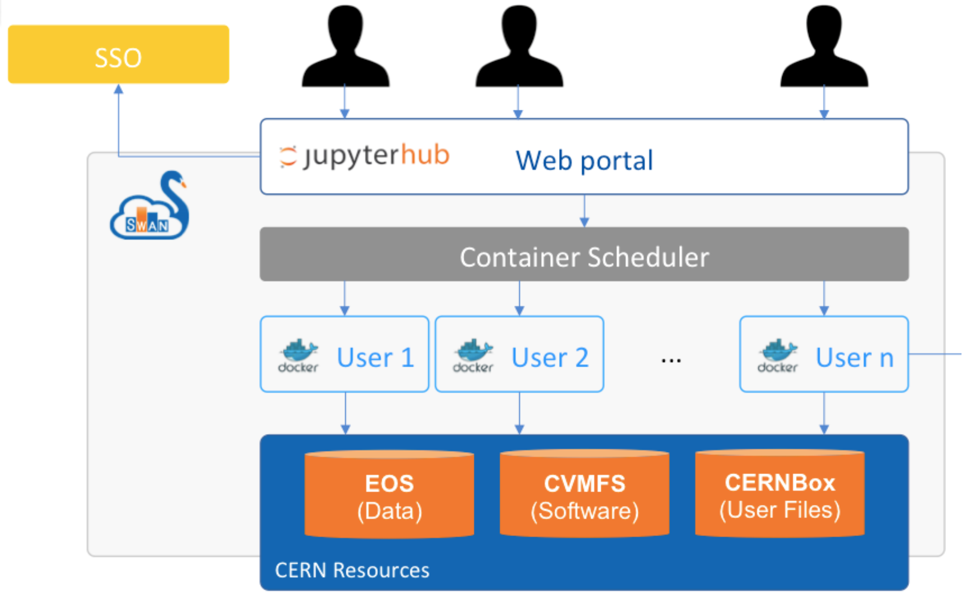


web-based analysis

swan.web.cern.ch

Parallel Sessions
[Facilitating collaborative analysis in SWAN]





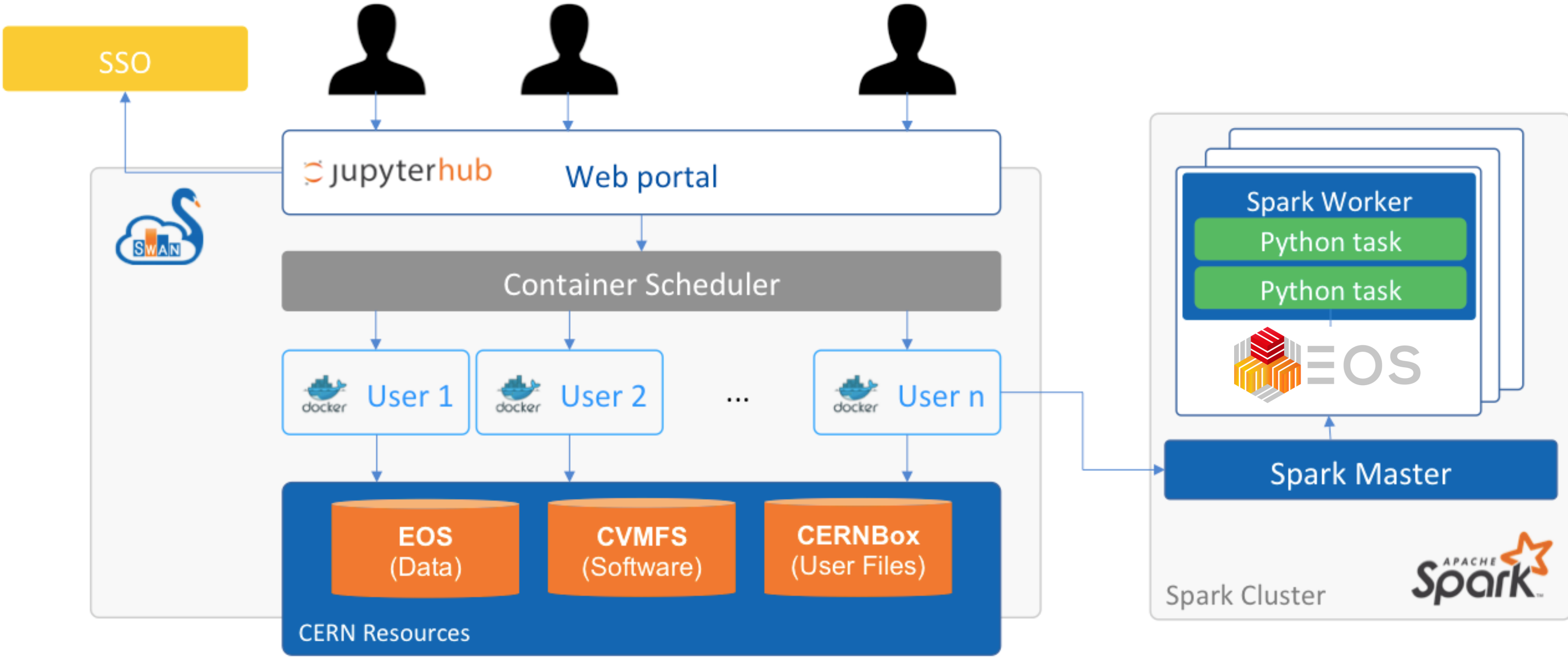
service architecture

CERN

SWAN provides interactive analysis front-end using JUPYTER notebooks

2017++ EOS

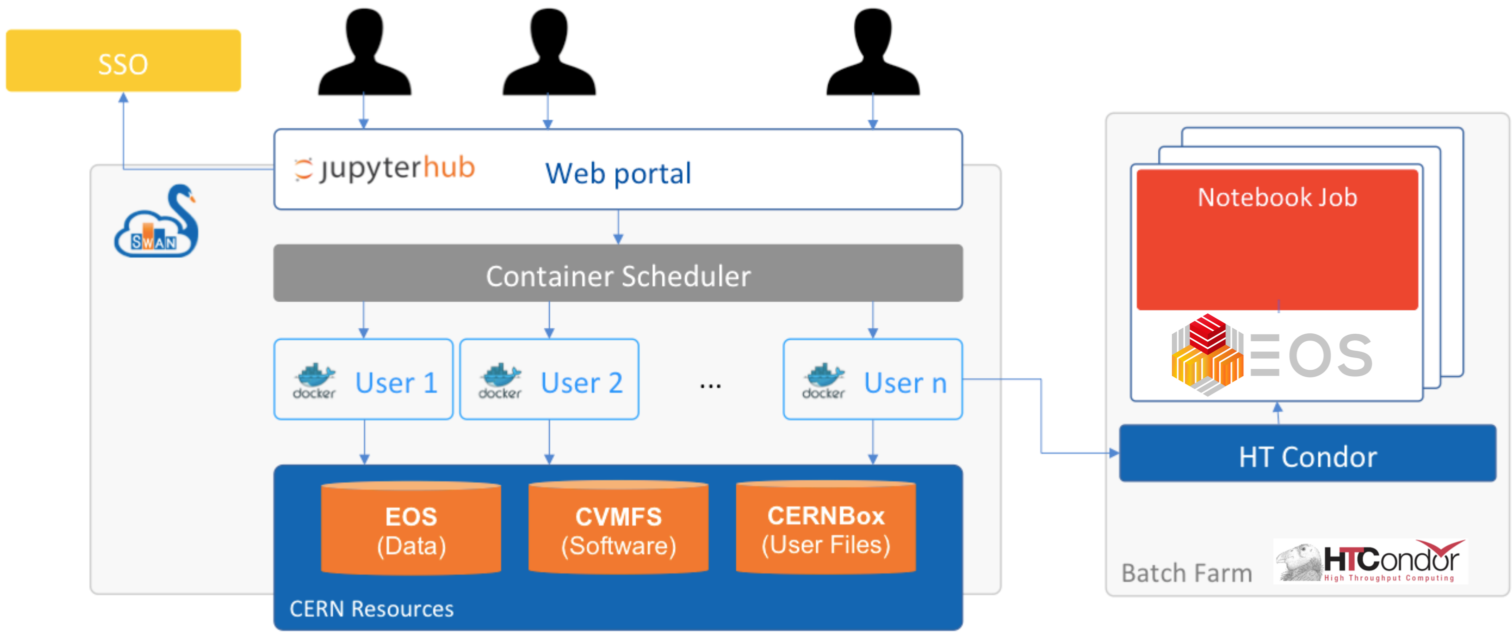
SWAN & compute



SWAN interfacing to Spark Cluster

2018++ EOS

SWAN & compute



Google
Summer of Code

next: SWAN interfacing to Batch Cluster

2017++

EOS

packaged eco-system

Science Box

EOS + CERNBox + SWAN

docker

docker-compose

kubernetes

One-Click Demo Deployment

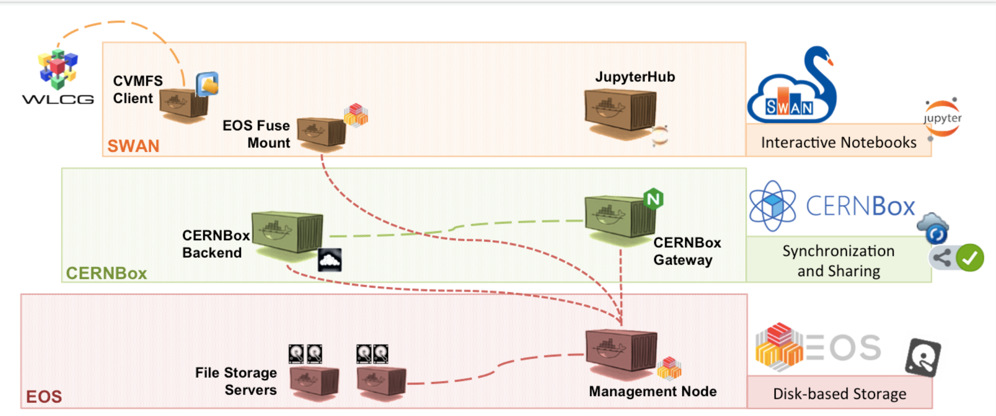
- Single-box installation via **docker-compose**
- No configuration required
- Download and run services in 15 minutes

https://github.com/cernbox/uboxed

Production-oriented Deployment

- Container orchestration with **Kubernetes**
- Scale-out storage and computing
- Tolerant to node failure for high-availability

https://github.com/cernbox/kuboxed



Science Box provides an easy demo & production platform

2018++

EOS + Tape = EOSCTA

Parallel Sessions
CERN Tape Archive: From Development to Production Deployment

integrated support for tape into EOS file on tape=offline replica

- loose service coupling between EOS and CTA via protocol buffer interface & notification events
- no SRM, using XRootD protocol only for now - integrated with FTS
- pre-production service for ATLAS available

high disk capacity

EOSATLAS

TPC

low disk capacity

EOSATLASCTA

short file lifetime

Operation Model

Cern Tape Archive

Mid-term plan to migrate CASTOR data to CTA

2018++ EOS

eosxd - a filesystem client for EOS

Why this is important but difficult …

- mounted filesystem access is required to enable storage access to any software *out of the box*

- filesystem development is difficult and lengthy

  AFS V1,2,3 - **35 years**
  NFS V1,2,3,4 - **34 years**
  cephfs - **12 years** - production version announced after 10 years!

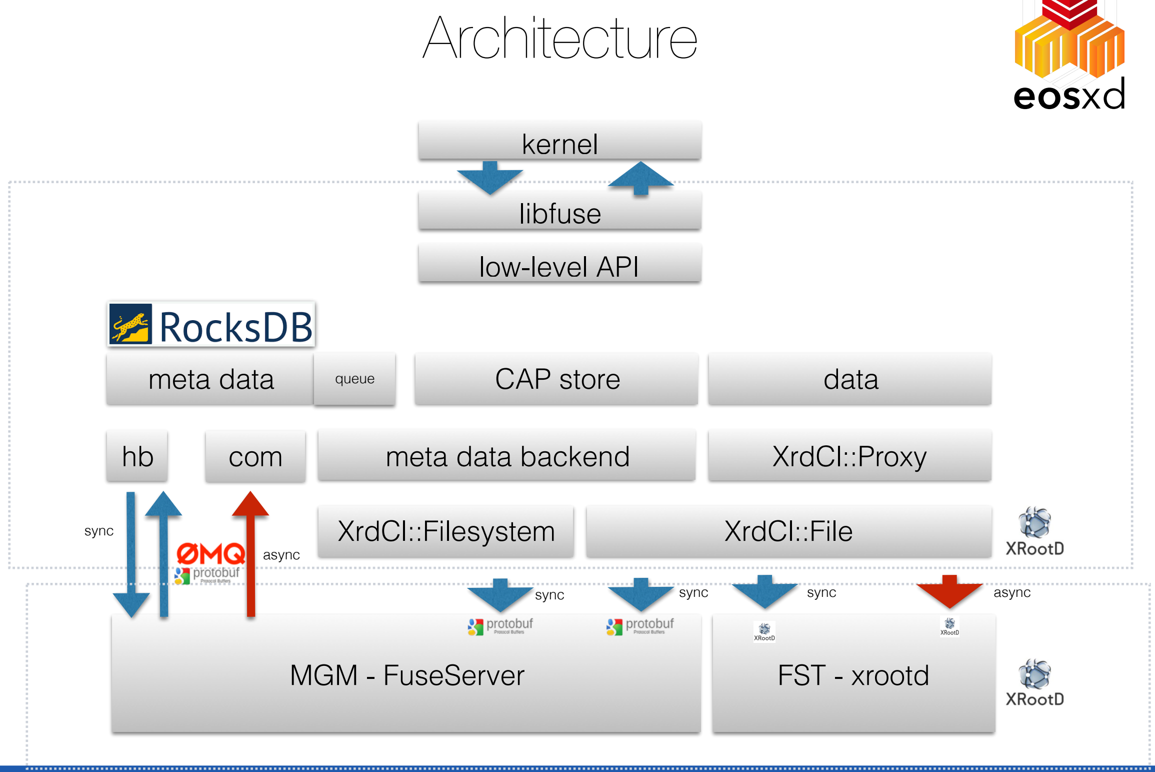
- EOS filesystem client rewrite started Q4 2016: **eos**d => **eos**xd

CERN

Question: **how far can you get with a user-space filesystem implementation?**

eosxd

filesystem daemon



- enough **POSIX**ness
- file **locks**, byte-range locks
- hard **links** within directories
- rich **ACL** client support
- local **caching**
- **bulk deletion**/protection
- strong **security** & mount-by-key
- user,group & project **quota**
- implemented using **libfuse**

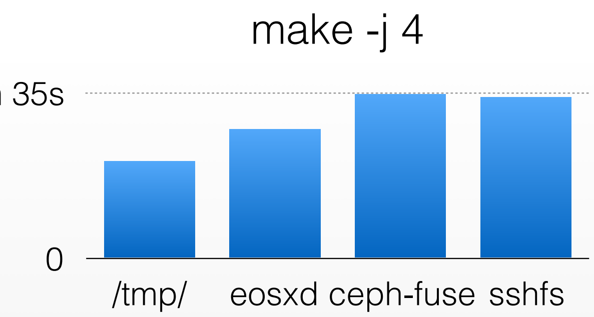
eosxd **provides POSIXness very similar to AFS**

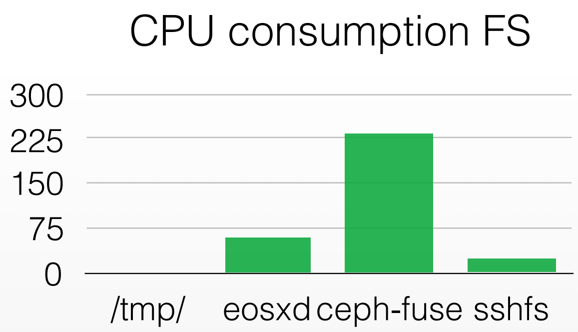
2018++ EOS

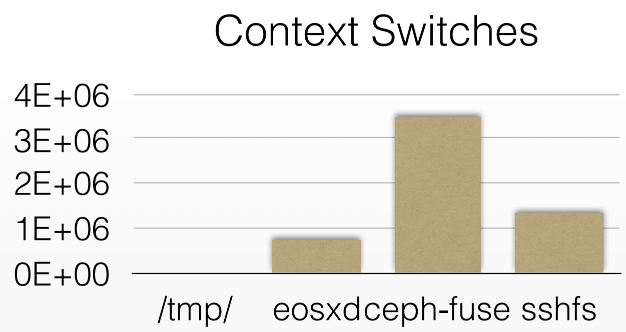
eosxd

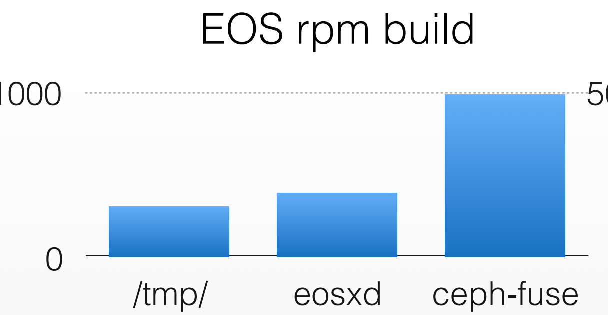
FUSE filesystem daemon

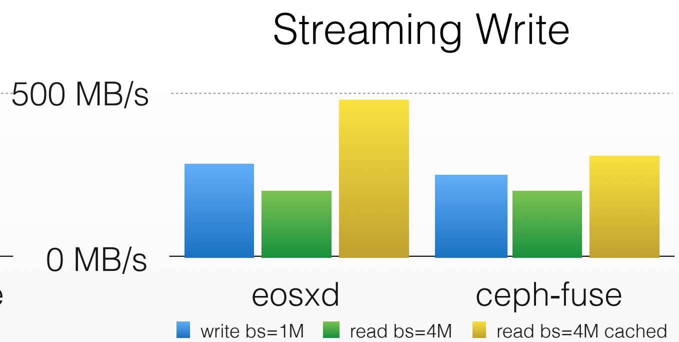
CAUTION
take benchmarks indicative

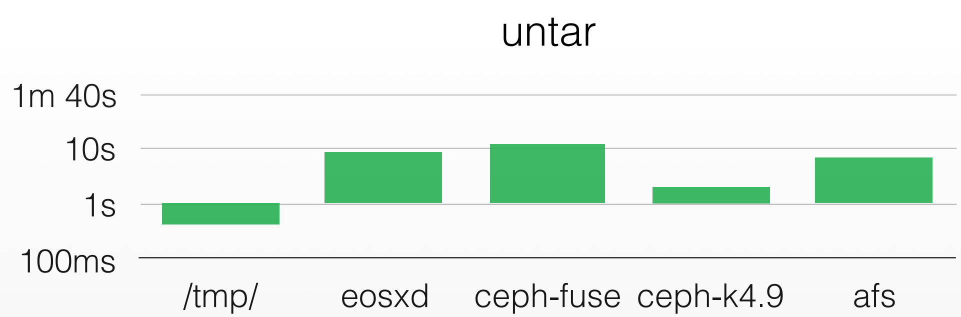












CERN

eosxd good performance with low resource usage

for a filesystem implemented in user space

eosxd

Strong Security Model

application runtime: **export KRB5CCNAME or X509xxx**

eosxd — **kerberos or X509 authentication** → eos

ACL per directory by mapped uid/gid

sys.acl=u:foo:rwx

before mount: **export XrdSecsssENDORSEMENT=<secret>**

eosxd — **shared secret authentication** → eos

ACL per directly by exported secret

sys.acl=k:B8E776C5-F5B2-4EF1-B2C3-64CB7C158FF3:rwx

clients **exports environment variables** in application context
to configure strong authentication - ***root*** role on client is **unavailable**

eosxd

sub-mount feature

glue external filesystems

- **Question:** can we integrate seemingly external filesystems into an EOS mount keeping their full performance?

- automount is a proven solution, but it has a static configuration and can not be configured by a user on the fly

```
/eos/user/f/foo/                    → EOS area
/eos/user/f/foo/software/root6      → software image
/eos/user/f/foo/hpc                 → manila share
/eos/user/f/foo/s3                  → S3 bucket
/eos/user/f/foo/backups             → backup snapshots
```

Short answer: yes we can!

2018++ EOS

eosxd

sub-mount feature

glue external filesystems

- allows **eos**xd to mount on-the fly any kind of filesystem described by a symbolic link in the EOS namespace
  - implemted: **squashfs** images with e.g. software distributions …
    - extremely space efficient file distribution with **zstd** compression, export millions of small files as a single image file
    - high-performance kernel module or FUSE module available

```
-rw-r--r--    1 nobody    nobody       256622592 Jun 29 18:04 .gcc-4.9.3.sqsh
lrwxrwxrwx    1 nobody    nobody               1 Jun 29 18:04 gcc-4.9.3 -> squashfuse:
```

  - envisaged: **external filesystem** areas e.g. high-performance *manila* shares, *s3* buckets etc. …
    - store cephx or s3 key as private extended attribute in EOS
  - envisaged: *restic* **backup snapshots** of user areas with restore password in extended attributes in EOS
    - browse/recover existing backups stored in an external instance without help from a service manager

WORK IN PROGRESS

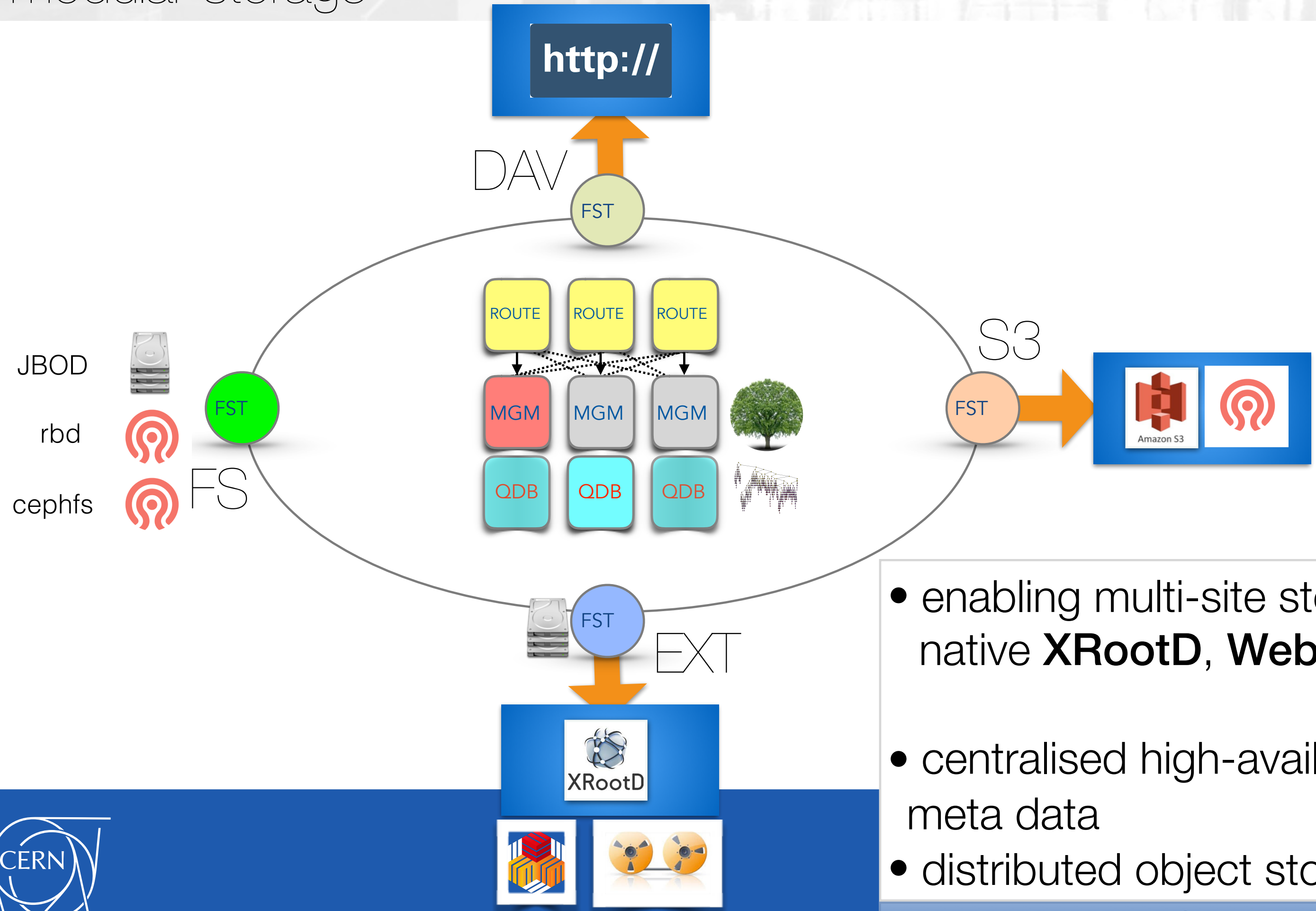
```
EOS Console [root://localhost] |/eos/wfe/submount/> squash
usage: squash new <path>                                         : create a new squashfs under <path>
       squash pack <path>                                        : pack a squashfs image
       squash unpack <path>                                      : unpack a squashfs image for modification
       squash info <path>                                        : squashfs information about <path>
       squash rm <path>                                          : delete a squashfs attached image and its smart link
```

CERN

eosxd **leverages performance of external optimised filesystems**

2018++ EOS modular storage

Distributed Storage Architecture



- enabling multi-site storage supporting native **XRootD**, **WebDav**, AWS/CEPH **S3** or **FS** storage
- centralised high-available namespace in KV store for meta data
- distributed object store for data

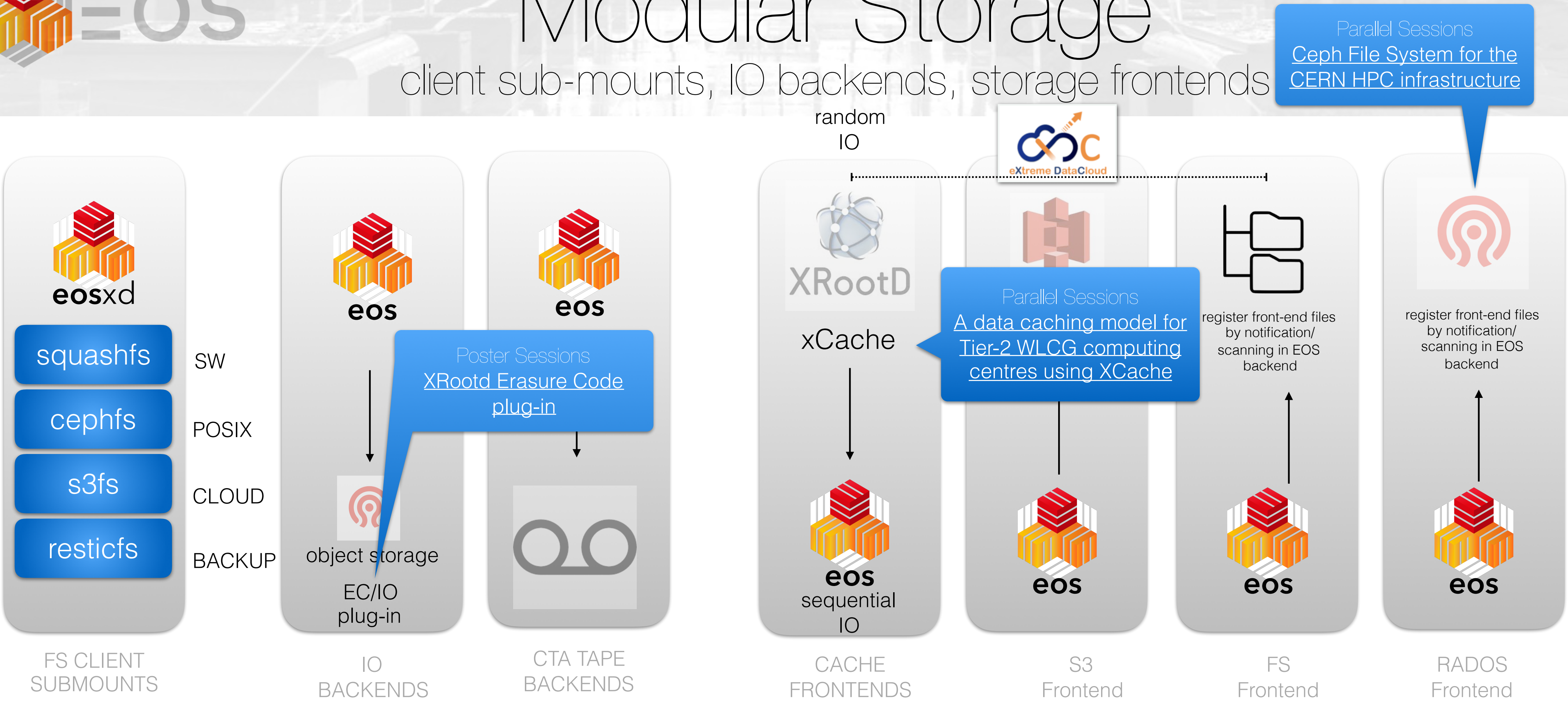
- distributed object store for data

eXtreme DataCloud

2018++ EOS

Modular Storage

client sub-mounts, IO backends, storage frontends

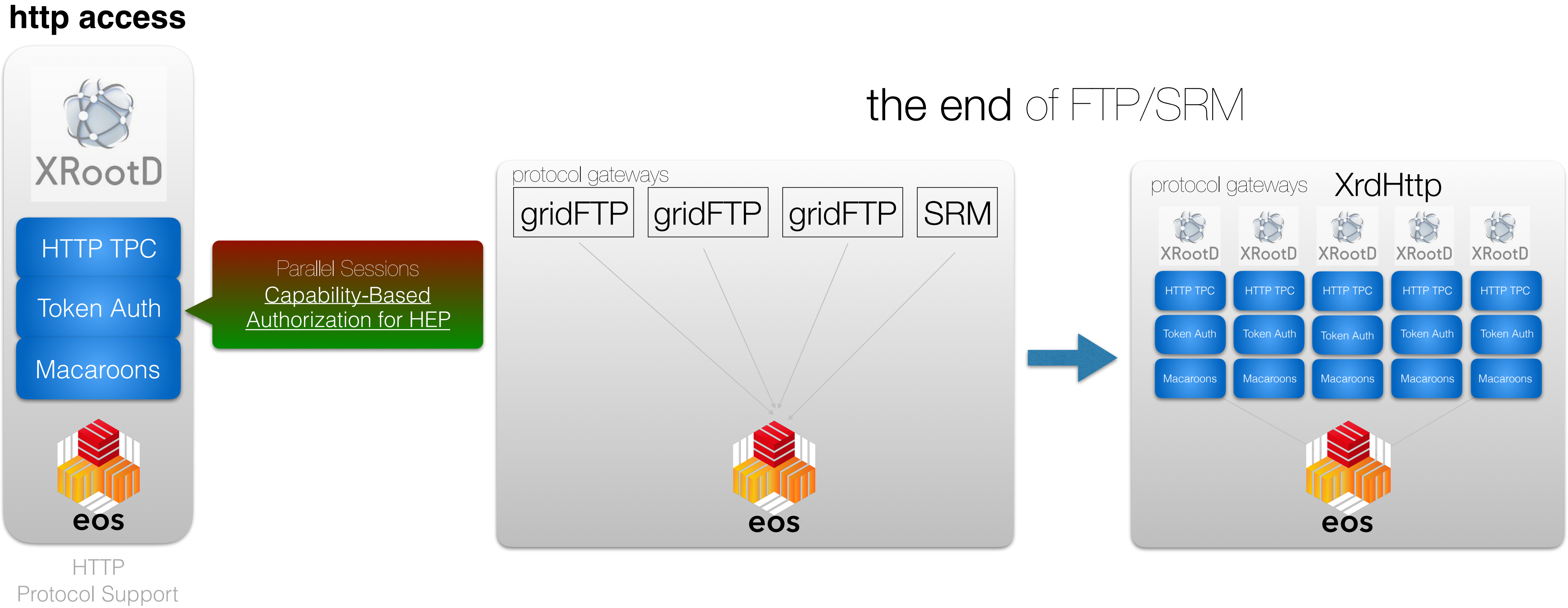


CERN

Storage modules allow extensions and replacement of custom low-level functionality with external solutions

Modular Storage

XRootD http ecosystem



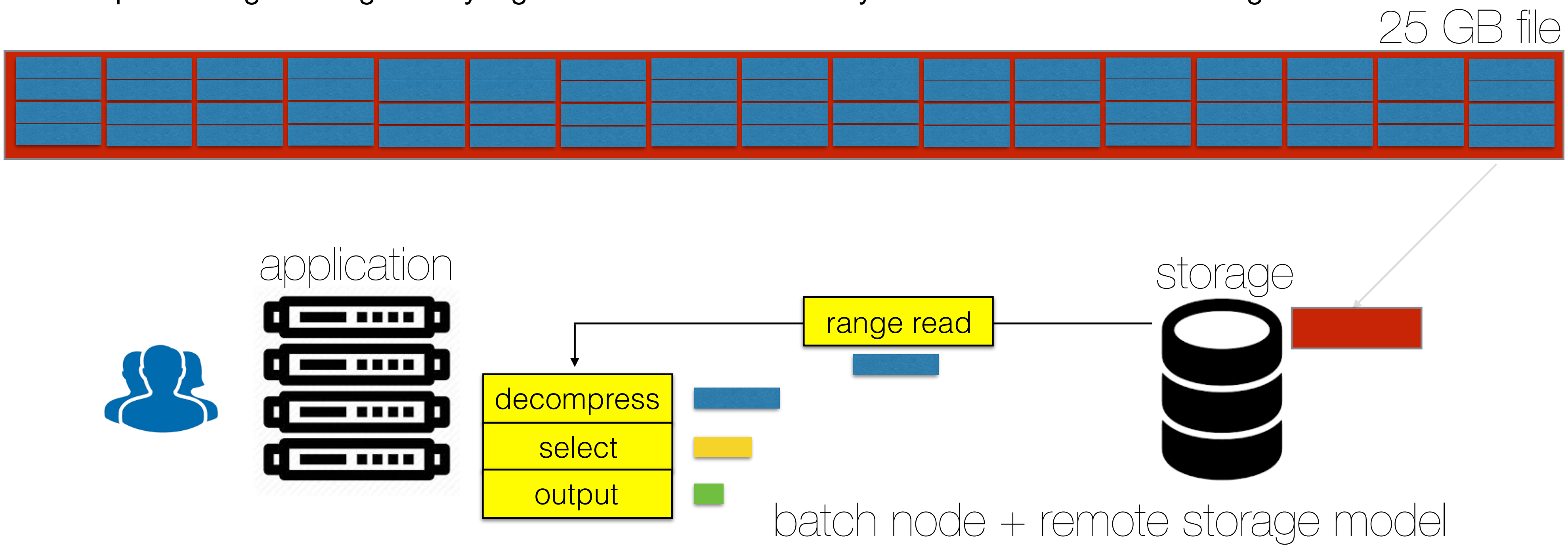
XRootD is growing a complete set of plug-ins for HTTP enabled storage allowing decommissioning of gridFTP/SRM soon(ish)

rEvolution
of data processing & storage
using object storage (?)

for a moment assume EOS → **E**xabyte-scale **O**bject **S**torage

Our conventional file processing model

Parallel processing of a large file by e.g. 10k subtasks is not very scalable/efficient when using POSIX I/O.



Do we need to change this simple model?

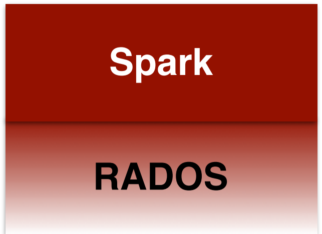
What are others proposing ...

Why Spark on Ceph? (Part 1 of 3)

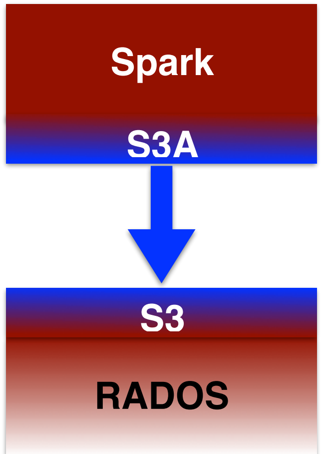
Posted on: June 25, 2018

https://redhatstorage.redhat.com/2018/06/25/why-spark-on-ceph-part-1-of-3/

Sounds HADOOP-like



but **means** only
S3 remote reading



Conclusion in this article:

Not highest possible performance when **storage and compute** are **separated** but the most flexible model when you have many people sharing infrastructure.

We figured that out already. **That is what we did and do**!

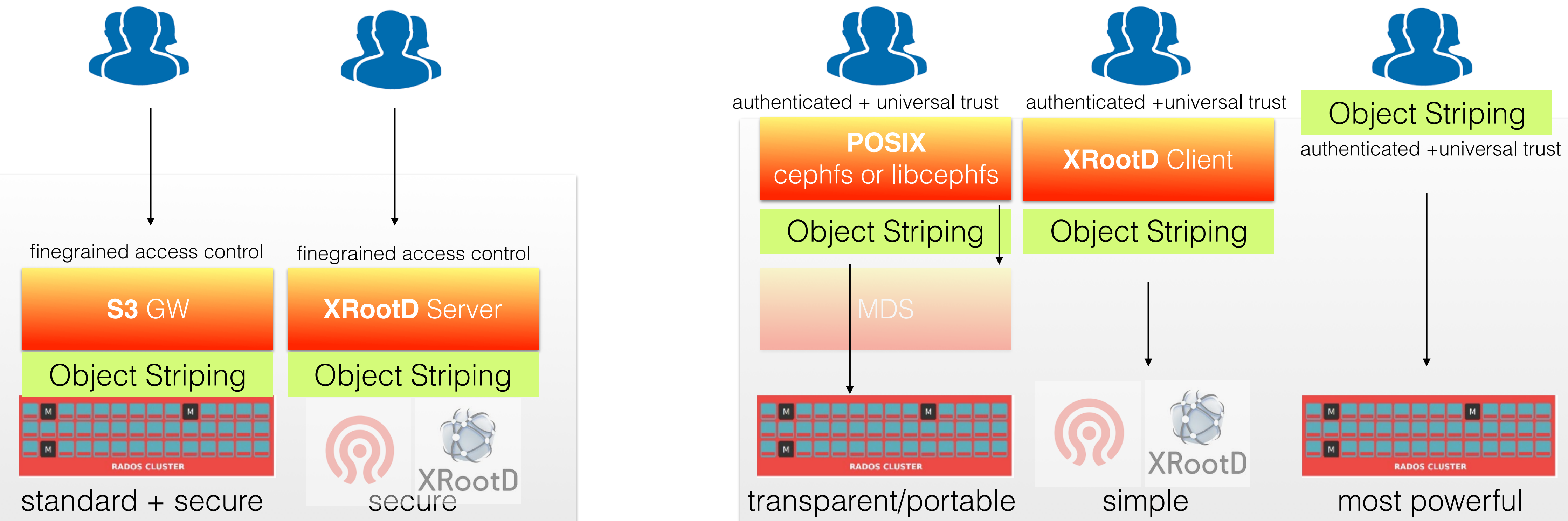
positive+ CEPH S3 buckets can be configured to be index-less removing a scalability limitation [sacrifying listings & accounting]
negative- CEPH S3 for HEP analysis misses multi byte-range request and data flows via gateways. Good news: that could be fixed!

Most people mean S3 when they talk about Object Storage

In fact applications know nothing about objects

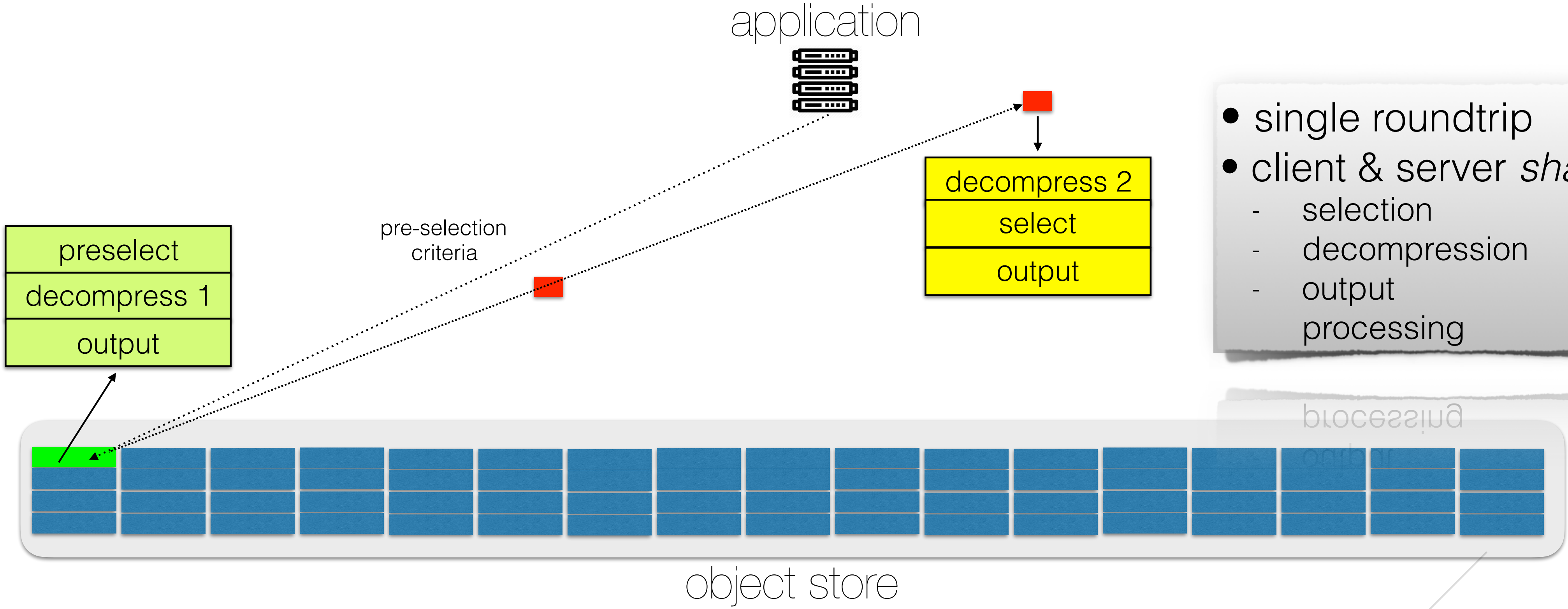
Object Storage Usage Models

… mainly about Parallel IO



There are many ways to do the same thing with subtle differences in complexity & functionality. Which one is the best? … depends …

Data processing with application object awareness

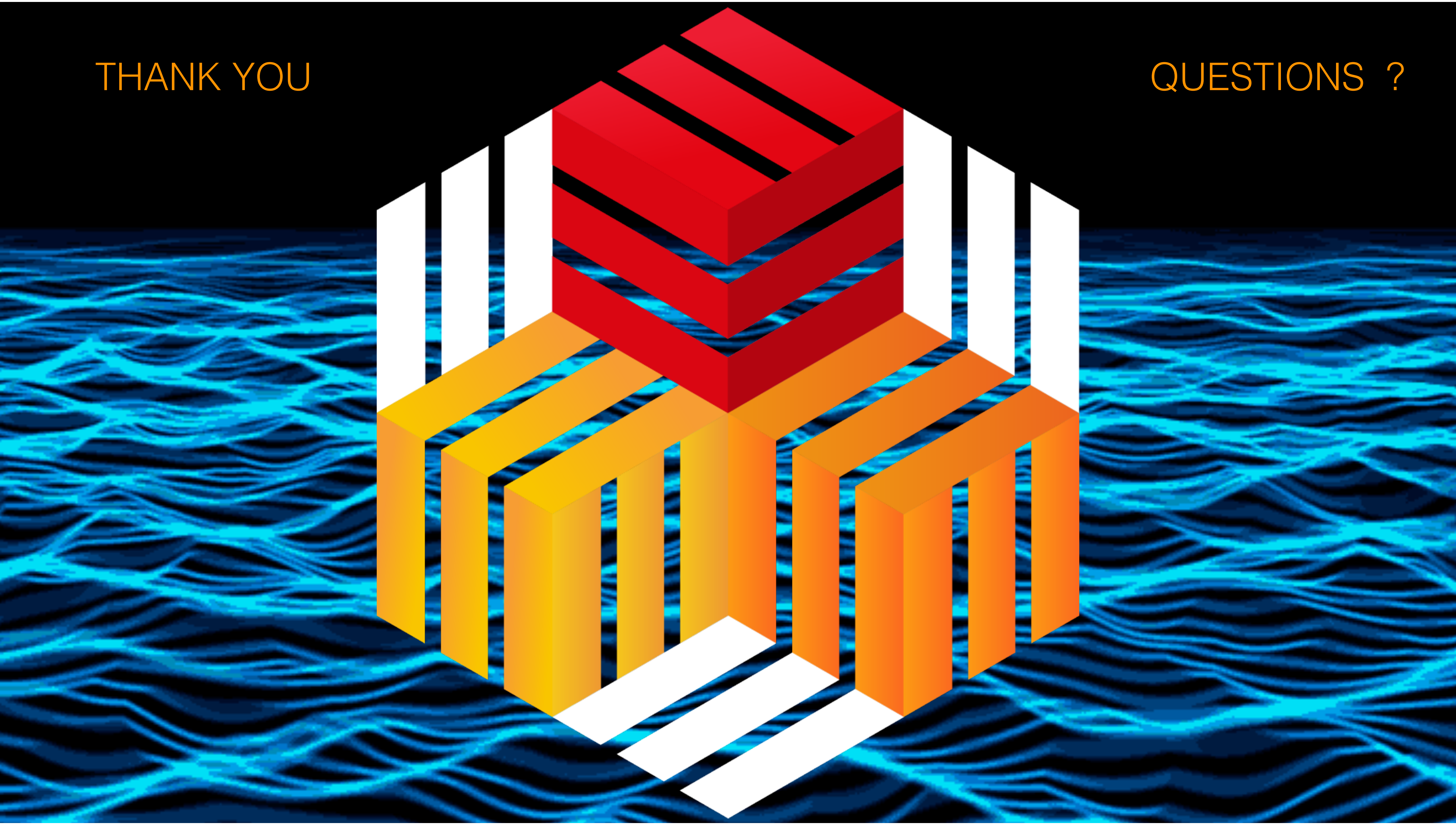


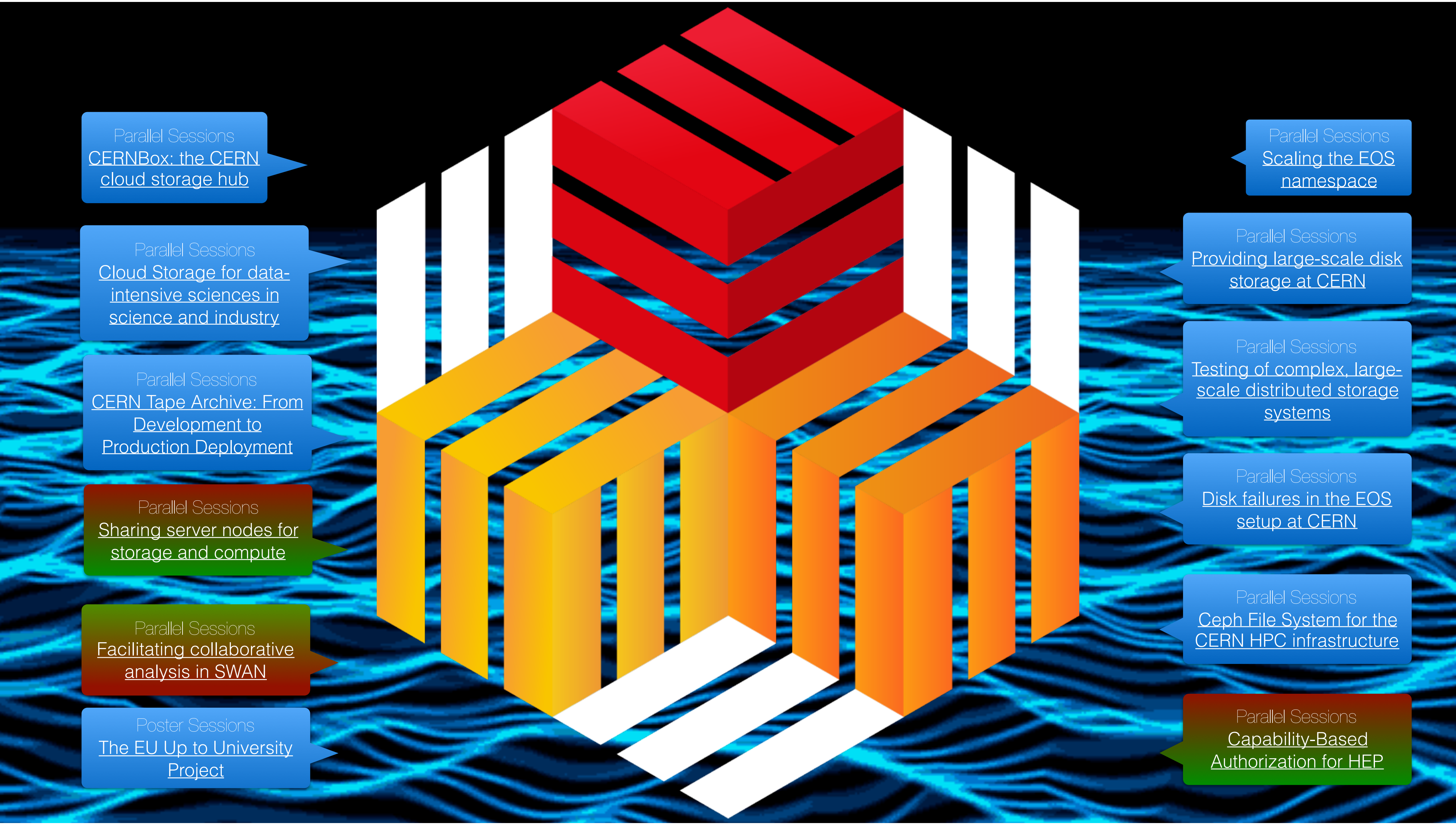
- single roundtrip
- client & server *share*
  - selection
  - decompression
  - output processing

Allows to move some IO processing inside the object storage
non-generic but use-case optimised approach - nice R&D

Summary & Outlook

- EOS has been under **steady evolution** since 8 years.
  - major promoter of XRootD as a framework and remote access protocol in HEP
  - CERN service had overrun **design limitation** in meta-data & data size during 2017 with visible impact
  - this year marks a major architectural change for scalability, availability & usability
- EOS converges towards an **integrative platform** of external storage components and services **for scientific data processing**
  - it leaves flexibility to integrate new ideas & requirements easily e.g. CERNBOX/SWAN/EOS eco-system
  - open to paradigm shift: leverage low-level components and implement high-level storage functionality
- Exabyte-scale Object Storage is an interesting technology to consider for LHC Run3
  - requires a detailed evaluation of the performance/cost model for storage and possible application benefit. Simplest approach is to build storage tiers and hide objects completely from applications. In this case: nothing visible will change for applications!


THANK YOU
QUESTIONS ?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