Data management services

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Data and Storage Services

EBI-CERN workshop
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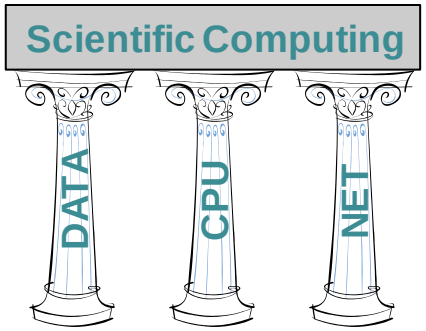
What is data management ?

- Scientific research in recent years has exploded the computing requirements
  - Computing has been the strategy to reduce the cost of traditional research
  - Computing has opened new horizons of research not only in High Energy Physics
- Data management is one of the three pillars of scientific computing



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Data management at CERN

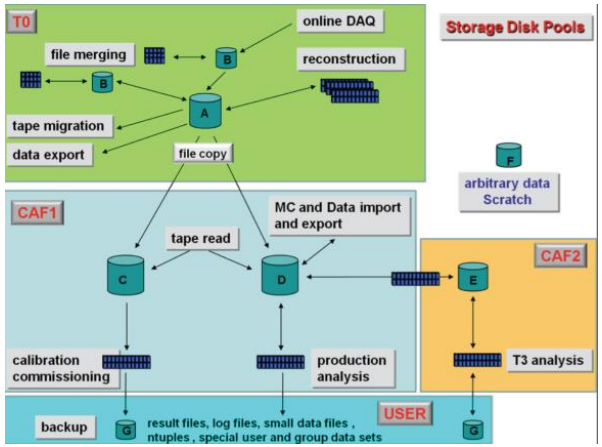
- Some numbers
  - 80’000 disks, 125’000 Terabytes, 1500 servers
  - More than 50’000 TB of user data on disks
  - 123 Tape drives, 52’000 tape cartridges, 105’000 TB of capacity, 95’000 TB of physics data
  - Data inflow: ~ 6.5 GB/s, sustained
  - Status pages:
    - http://eos.cern.ch/
    - http://castor.web.cern.ch/
    - http://sls.cern.ch/sls/dcbynum.php

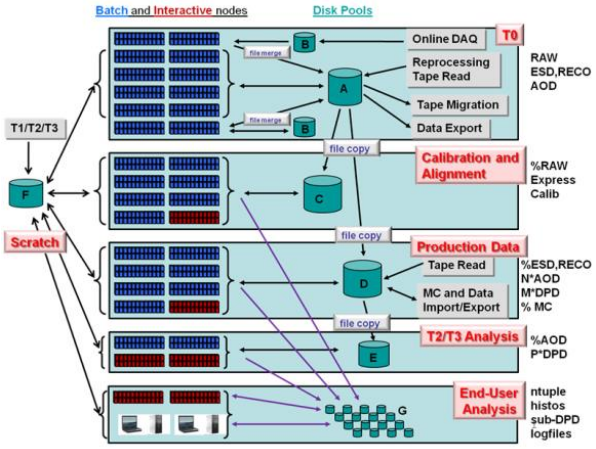
What is data “management” ?

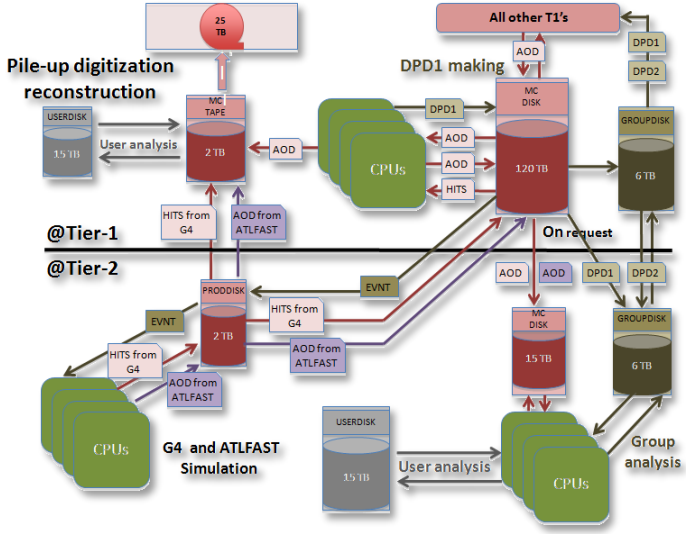
- Data Management solves the following problems
  - Data reliability
  - Access control
  - Data distribution
  - Data archives, history, long term preservation
- In general:
  - Empower the implementation of a workflow for data processing

What is data management ?

- Examples from LHC experiment data models



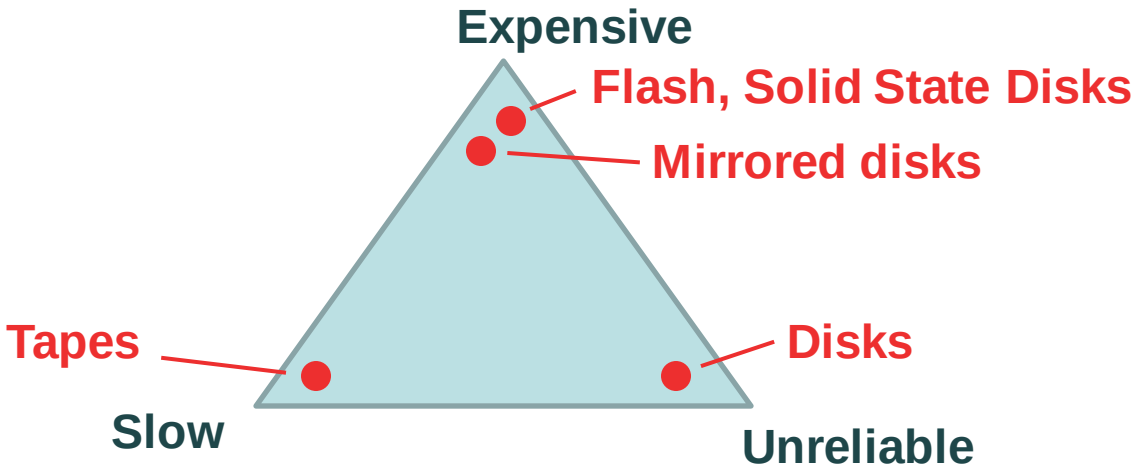




- **Two building blocks to empower data processing**
  - Data pools with different quality of services
  - Tools for data transfer between pools

Data pools

- Different quality of services
  - Three parameters: (Performance, Reliability, Cost)
  - You can have two but not three



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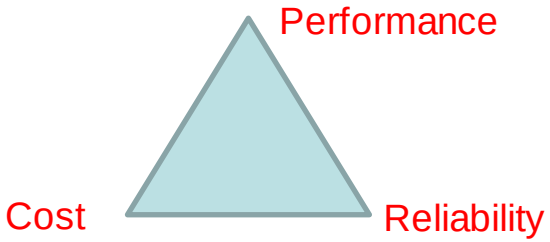
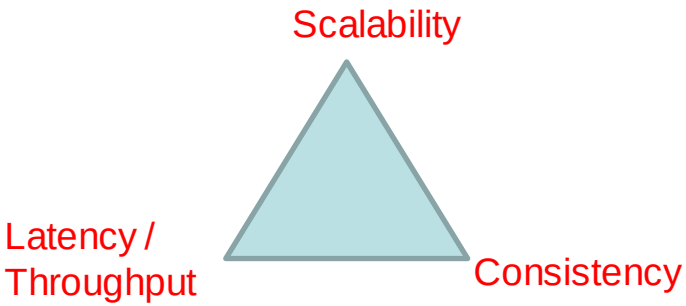
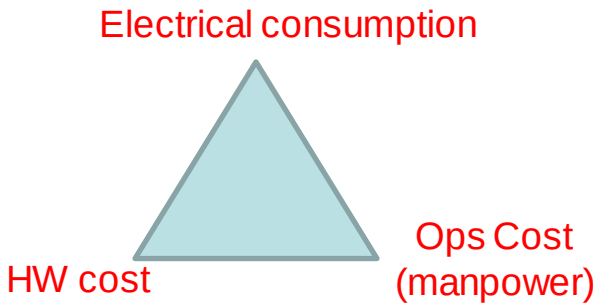
But the balance is not as simple

- Many ways to split (performance, reliability, cost)



- Performance has many sub-parameters
- Cost has many sub-parameters
- Reliability has many sub-parameters





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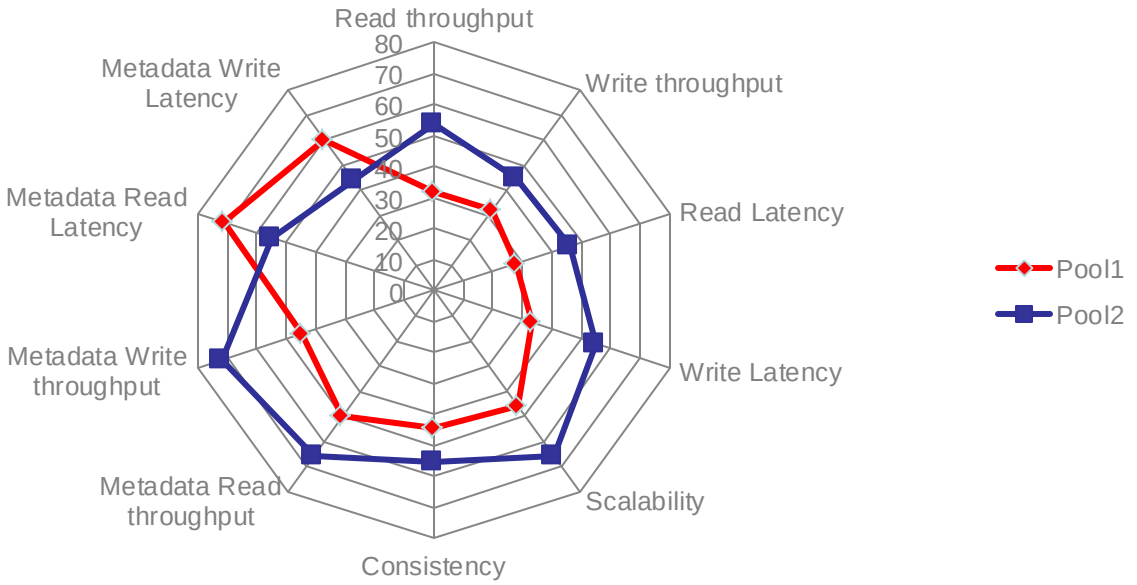
And reality is complicated

- Key requirements: Simple, Scalable, Consistent, Reliable, Available, Manageable, Flexible, Performing, Cheap, Secure.
- Aiming for “à la carte” services (storage pools) with on-demand “quality of service”
- And where is scalability ?



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Areas of research in Data Management

Reliability, Scalability, Security, Manageability

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Storage Reliability

- Reliability is related to the probability to lose data
  - Def: “the probability that a storage device will perform an arbitrarily large number of I/O operations without data loss during a specified period of time”
- Reliability of the “service” starts from the reliability of the underlying hardware / media
  - Example of disk servers with simple disks: reliability of service = reliability of disks
- But data management solutions can increase the reliability of the hardware at the expenses of performance and/or additional hardware / software
  - Example: disk mirroring, Redundant Array of Inexpensive Disks (RAID)

Do we need tapes ?

- Tapes have a bad reputation in some use cases
  - Slow in random access mode
    - high latency in mounting process and when seeking data (F-FWD, REW)
  - Inefficient for small files (in some cases)
  - Comparable cost per (peta)byte as hard disks

- Tapes have also some advantages
  - Fast in sequential access mode
    - > 2x faster than disk
    - physical read after write verification (makes > 4x faster than disks)
  - Several orders of magnitude more reliable than disks
    - Few hundreds GB loss per year on 80 PB tape repository
    - Few hundreds TB loss per year on 50 PB disk repository
  - No power required to preserve the data
  - Less physical volume required per (peta)byte
  - Inefficiency for small files issue resolved by recent developments
  - Nobody can delete hundreds of PB in minutes
- Bottom line: if not used for random access, tapes have a clear role in the architecture

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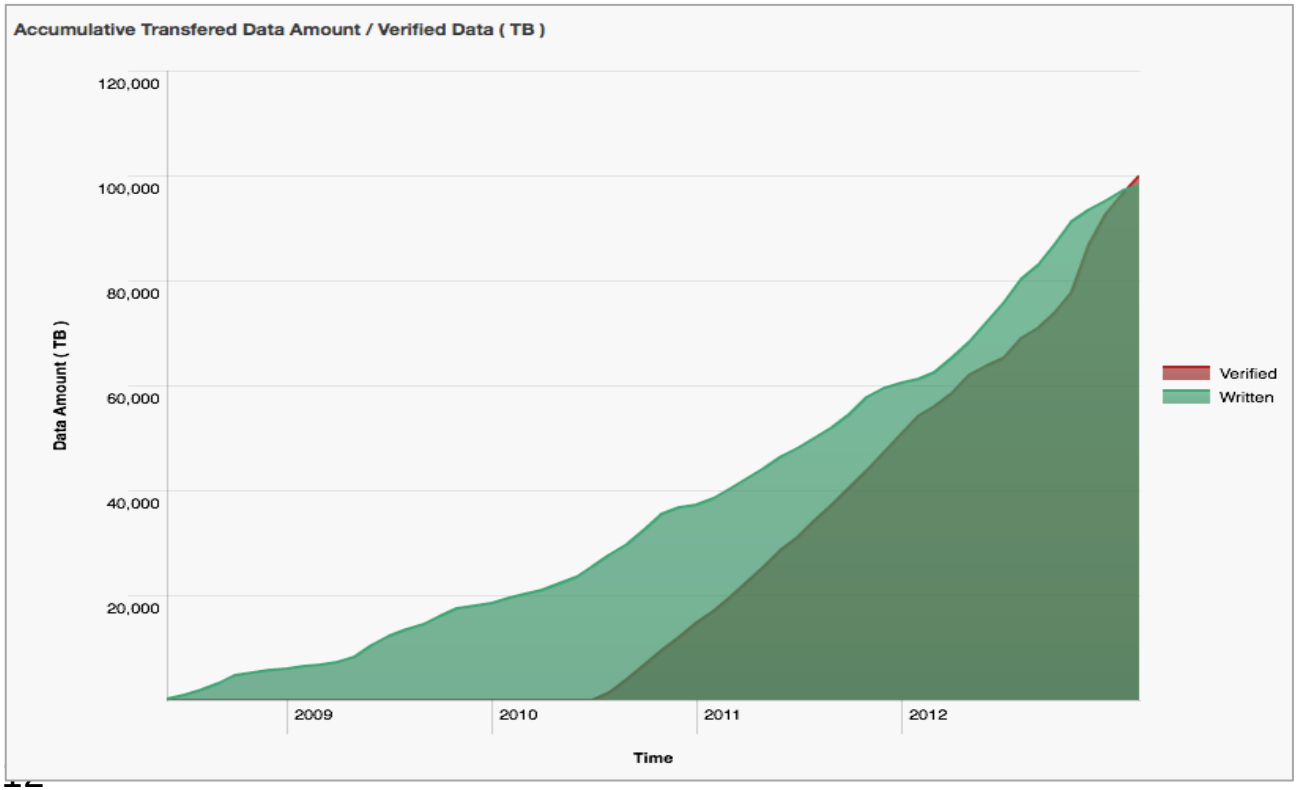
Example: tape verification at CERN

- Turnaround time: ~2.6 years @ ~1.26GB/s for 100 PB
  - 10-12 drives (~10%) @ 90% efficiency
- Measured data loss: ~ 65GB lost over 69 tapes



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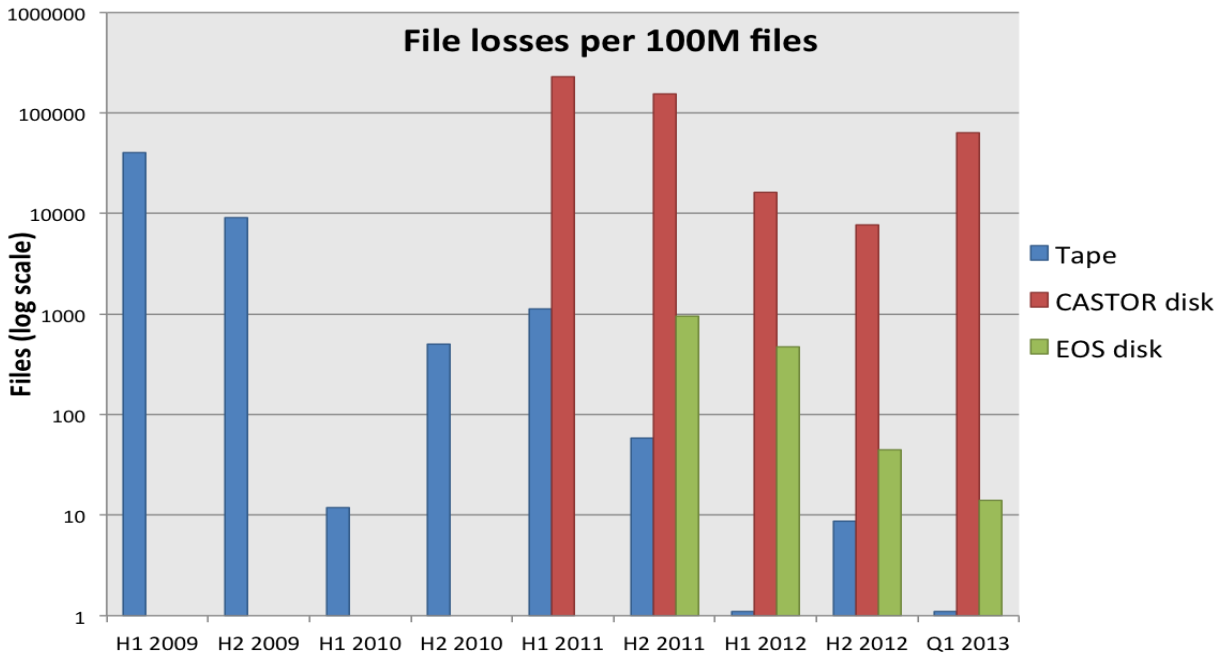
Measuring reliability

- "Disk pool" reliability is higher than "raw disk" reliability because we increase it within the service (replication, error correction, ….)
- Tape reliability still ~O(1) higher than disk with error correction !
  - Note: single tape copy vs. redundant copies on disk



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Types of arbitrary reliability

- Plain (reliability of the service = reliability of the hardware)

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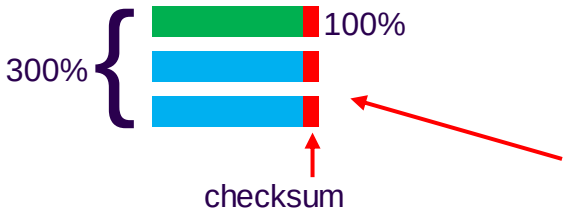
Types of arbitrary reliability

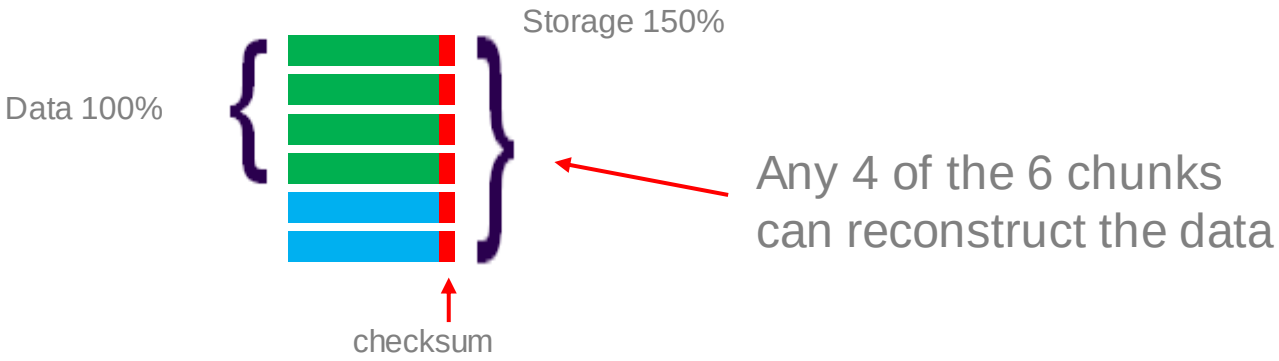
- Plain (reliability of the service = reliability of the hardware)
- Replication
  - Reliable, maximum performance, but heavy storage overhead
  - Example: 3 copies, 200% overhead



Any of the 3 copies is enough to reconstruct the data

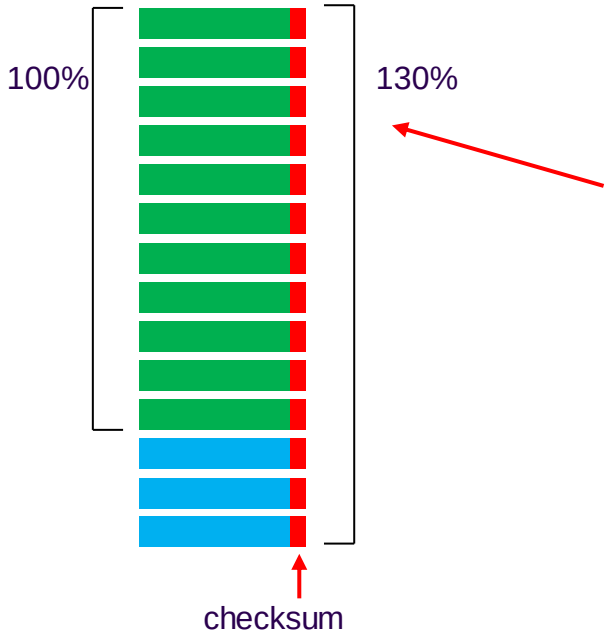
Types of arbitrary reliability (summary)

- Double parity / Diagonal parity
  - Example 4+2, can lose any 2, remaining 4 are enough to reconstruct, only 50 % storage overhead



Types of arbitrary reliability

- Plain (reliability of the service = reliability of the hardware)
- Replication
  - Reliable, maximum performance, but heavy storage overhead
  - Example: 3 copies, 200% overhead
- Reed-Solomon, double, triple parity, NetRaid5, NetRaid6
  - Maximum reliability, minimum storage overhead
  - Example 10+3, can lose any 3, remaining 10 are enough to reconstruct, only 30 % storage overhead



Any 10 of the 13 chunks are enough to reconstruct the data

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Types of arbitrary reliability

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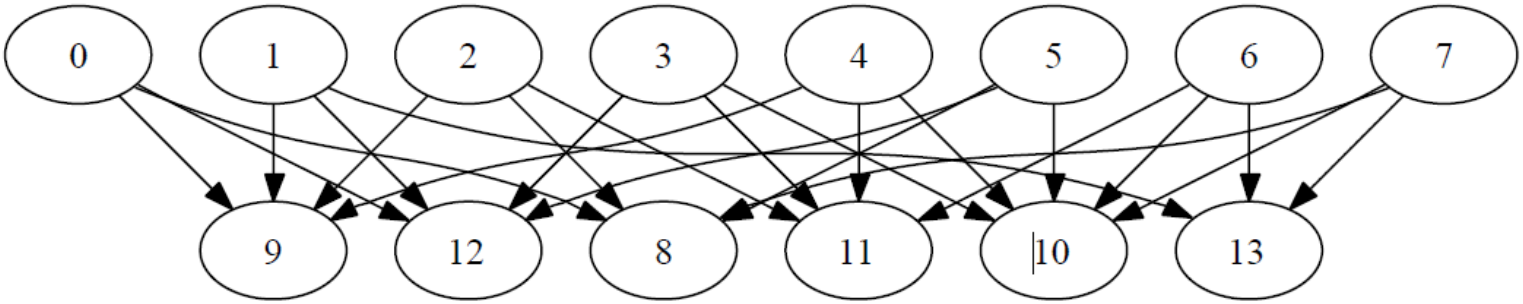
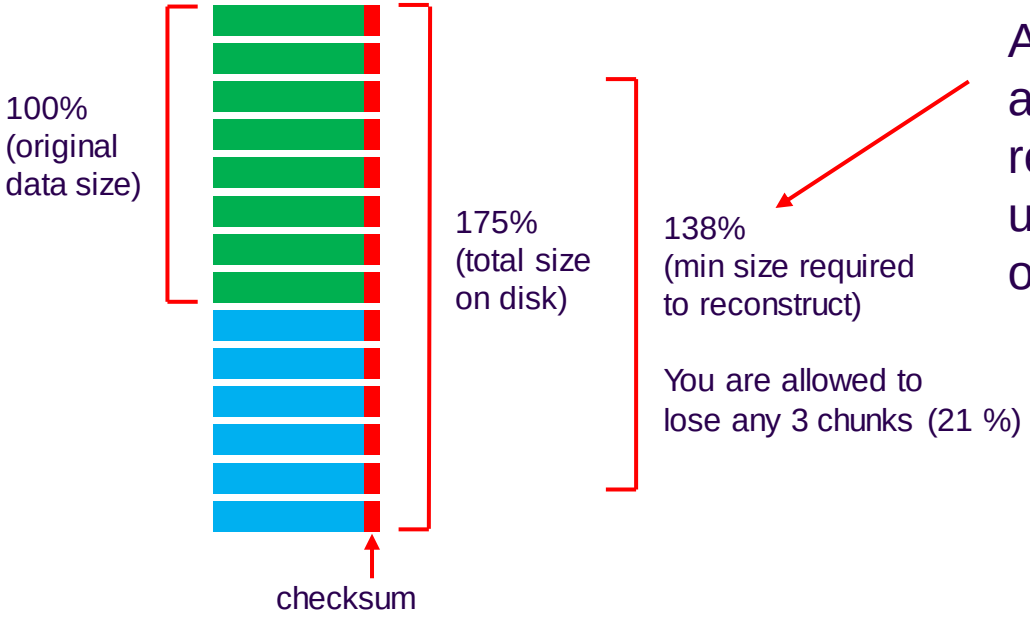
  - Maximum reliability, minimum storage overhead
  - Example 10+3, can lose any 3, remaining 10 are enough to reconstruct, only 30 % storage overhead
- Low Density Parity Check (LDPC) / Fountain Codes / Raptor Codes
  - Excellent performance, more storage overhead
  - Example: 8+6, can lose any 3, remaining 11 are enough to reconstruct, 75 % storage overhead (See next slide)

Example: 8+6 LDPC

0 .. 7: original data
8 .. 13: data xor-ed following the arrows in the graph





Any 11 of the 14 chunks are enough to reconstruct the data using only XOR operations (very fast)

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Reliability summary

- Plain (reliability of the service = reliability of the hardware)
- Replication
  - Reliable, maximum performance, but heavy storage overhead
  - Example: 3 copies, 200% overhead
- Reed-Solomon, double, triple parity, NetRaid5, NetRaid6
  - Maximum reliability, minimum storage overhead
  - Example 4+2, can lose any 2, remaining 4 are enough to reconstruct, 50 % storage overhead
  - Example 10+3, can lose any 3, remaining 10 are enough to reconstruct, only 30 % storage overhead
- Low Density Parity Check (LDPC) / Fountain Codes
  - Excellent performance, more storage overhead
  - Example: 8+6, can lose any 3, remaining 11 are enough to reconstruct, 75 % storage overhead
- In addition to
  - File checksums (available today)
  - Block-level checksums (available today)

Availability versus Reliability

- Reliability relates to the probability to loose data
  - However, you can have service interruptions and temporary unavailability of data without data loss
- Consequences
  - High data reliability does not imply high service availability
  - When hardware fails, the data on it becomes unavailable. It is a service failure
  - When experiencing service failure, an intervention must happen as fast as possible.
    - Requires a piquet with engineers on call
    - Draining and restore operations take lot of time, affecting also availability

Reserve slides on Availability

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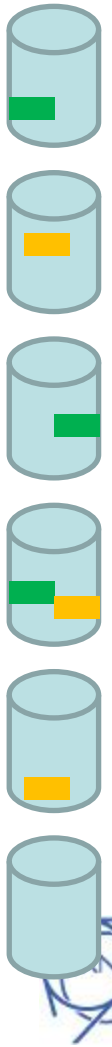
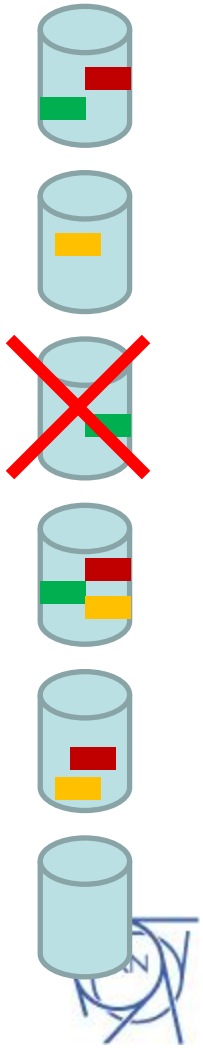
Example: High Availability with replication

- We have “sets” of T independent storage
  - This example has T=6
- The storage pool is configured to replicate files R times, with R < T
  - This example: R=3 every file is written 3 times on 3 independent storage out of the 6 available
  - When a client read a file, any copy can be used
  - Load can be spread across the multiple servers to ensure high throughput (better than mirrored disks, and much better than Raid 5 or Raid 6)



Example scenario: hardware failure

- The loss of a storage component is detected. The storage component is disabled automatically
- File Read requests can continue if R>1 (at least 1 replica), at reduced throughput
  - The example has R=3
- File Creation / Write requests can continue
  - New files will be written to the remaining T – 1 = 6 – 1 = 5 storage components
- File Delete request can continue
- File Write / Update requests can continue
  - Either by just modifying the remaining replicas or by creating on the fly the missing replica on another storage component
- Service operation continues despite hardware failure. (independent storage)



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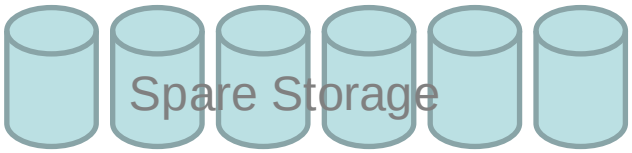
Example scenario: failure response

- The disabled faulty storage is not used anymore
- There is “Spare Storage” that can be used to replace faulty storage
  - manually or automatically
- The lost replicas are regenerated from the existing replicas
  - Manually or automatically



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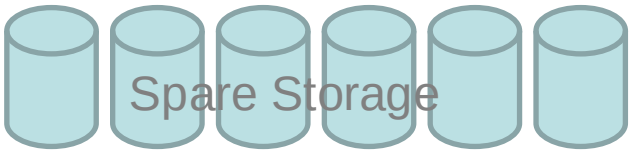
Example scenario: draining a server

- To drain a server, just power it off
- Will be seen as faulty and disabled (it will not used anymore)
- The available “Spare Storage” will be used to replace faulty storage
  - manually or automatically
- The lost replicas are regenerated from the existing replicas
  - Manually or automatically



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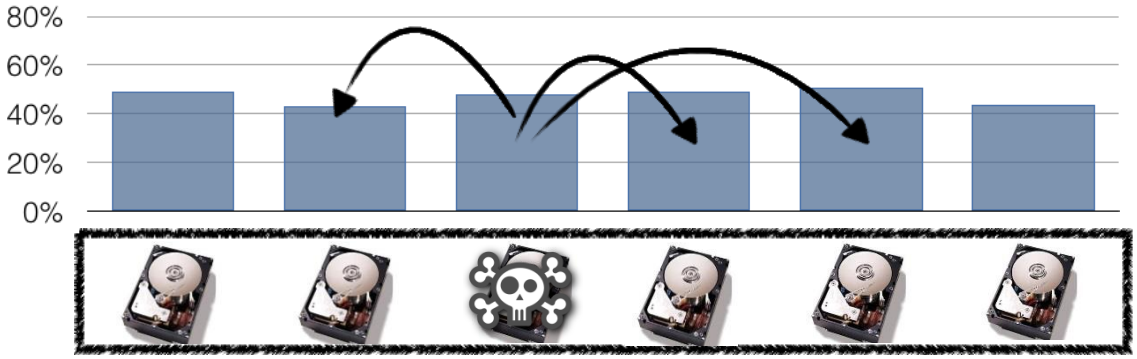
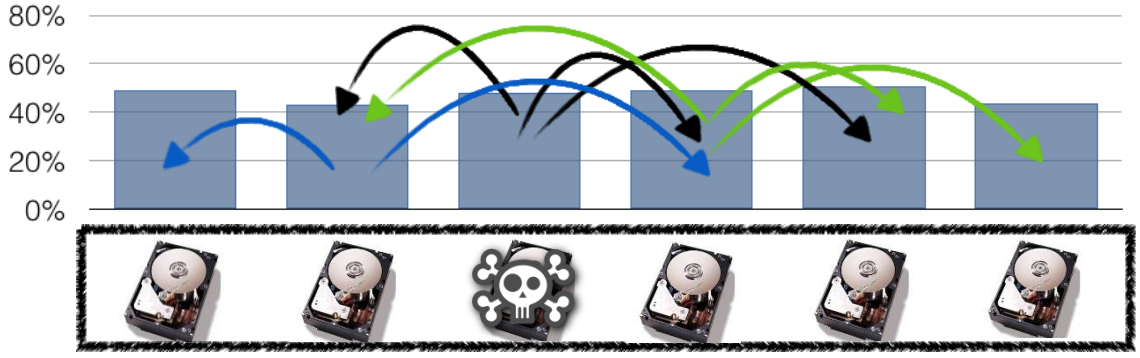
Draining example ...

CASTOR
CERN Advanced STORage manager



EOS



Service operations

- Ensure that there is enough spare storage to cope with:
  - Hardware failures
  - Planned replacement
- No need to intervene timely when Hw fails
  - Asynchronous interventions only
  - No engineers on call or piquet needed
- Create and configure data pools
- Arbitrary level of services: Monitor reliability, availability and performance and adapt the various parameters (storage size, T, R, …) to optimize the operational experience and meet the service level agreement
- Identify what responses can be automated and what needs to be handled manually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Conclusions

- Beware of the approach “all data in one pool”
  - Offers only one, common, quality of service
- It is important above a certain volume of data, to be able to optimize the cost to the real requirements, and go beyond “generic” solutions.