Large DBs on the GRID

Getting performance with wild HEP data distribution

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Outline

- The problem
  - The structured files
- Generic system architectures
  - Offline part, jobs, data, bookkeeping etc.
- Catalogues and metadata repositories
- Performance is important
- Jobs to the data or data to jobs?
- The xrootd way
- Direct access in WAN/LAN
- Storage cooperation

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The problem

- HEP experiments are very big data producers
- The HEP community is a very big data consumer
  - Analyses rely on statistics on complex data
  - Scheduled (production) processing and user-based unscheduled analysis
- Performance is a primary factor
  - The infrastructure must be able to guarantee access and functionalities
  - The softwares must use the infrastructures well

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Structured files

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- In the present times the computations are organized around very efficient “structured files”
  - See the presentation by Rene Brun
  - Which contain homogeneous data ready to be analyzed
  - At the various phases of HEP computing
  - Centrally-managed data processing rounds create the “bases of data” to be accessed by the community
  - One site is not enough to host everything and provide sufficient access capabilities to all the users

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The minimalistic workflow

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- In general, an user will:
  - Decide which analyses to perform for his new research
  - Write the code which performs it
    - Usually a high level macro or a "simple" plugin of an experiment-based software framework
  - Ask the system about the data requirements
    - Which files contain the needed information
  - Ask another system to process his analysis
  - Collect the results

Typically an experiment-based metadata repository and/or file catalogue

Typically the GRID (WLCG) or PROOF

This will likely become also his own computer as the hw performance increases and the sw allows it efficiently

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Databases

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- A DB as a “structured, heterogeneous base of data”
  - From the end of the 90s it became clear that putting **everything** in a relational or object-based orthodox DB was not a good choice
    - Versatility and expressive power comes at the expenses of performance, ease of maintenance and scalability
    - An insufficient performance also can cause big frustration and big system instabilities
    - Difficult to scale them at these extreme levels
      - Also the cost does not scale linearly
  - In practice, HEP data is typically composed by two sections:
    - The structured files, optimized for access performance
    - The metadata about them
      - A searchable repository of descriptions of what they contain
      - Support information

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Databases and storage

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- In simple words, the need is:
  - A bookkeeping repository able to do searches
    - With a big granularity, we are interested in big “datasets”, not in single events randomly spread somewhere
    - A relational/OO DB is perfect for that (order of 10^8 files per experiment)
  - An efficient and scalable data access system
    - ALL the performance of the hardware (disk pools) must be reachable
      - And scale linearly with it
    - If an app computes 15MB/s the disk will have to ‘see’ 15MB/s for it, not more.
    - Several processes hitting the same (remote) disk should not make its performance worse
      - In other words: the disk throughput must be exploited and it should scale
    - “Computes” means “computes”, not “transfer” or “consume”. This is very important.

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The GRID

- In its biggest simplification we can consider the GRID service (WLCG) as a huge batch system
  - Distributed worldwide
  - The user submits a job to process
  - This job is assigned to some worker node in some site
    - Through some mechanisms
    - E.g. nowadays a lot of user groups is using the “pilot job” paradigm
      - What is sent and scheduled is a “job agent”, which checks the environment first and then “pulls” the true job from an experiment-based service

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The Data Management

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- Files and datasets are stored into Storage Elements, hosted by sites
  - The decision is often taken when they are produced
- Processing jobs are very greedy
  - Up to 15-20 MB/s
- The GRID machinery (ev. Together with some service of the experiment) decides where to run a job
  - The service can also be human-based (!)
- Matching the locations of the data with the available computing resources is known as the “GRID Data Management Problem”.

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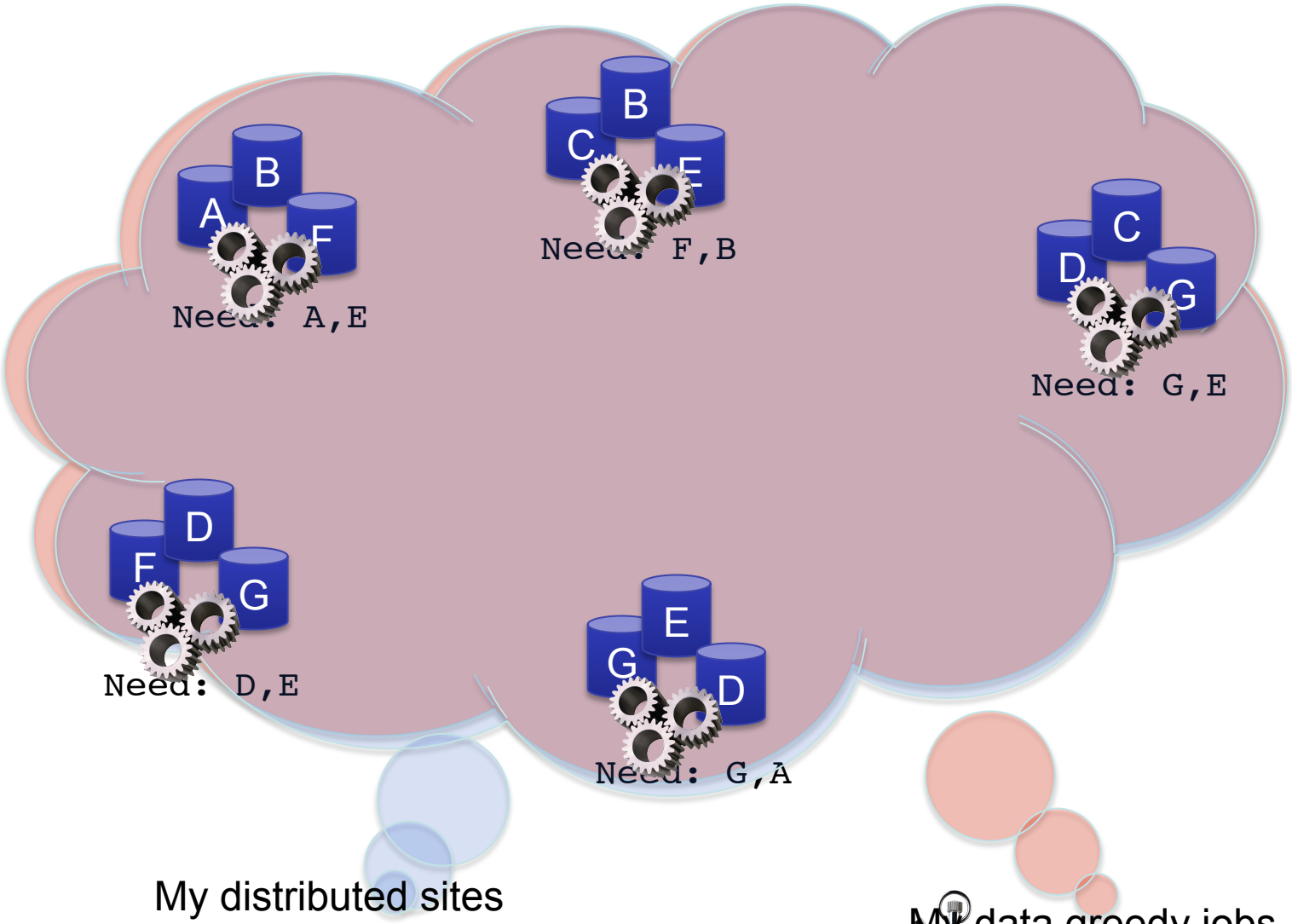
An example



My distributed sites
With pre-filled storage
With computing farms

My data greedy jobs

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Where to put the data?

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- Structuring the production/processing is a very hard problem
- There are basically 2 philosophies, plus a third addition:
  - Send the job in the same place as the data files it needs
    - Easy if there's only one very big input file for a job
    - Otherwise it degrades to a complex matching problem
  - Send the data where the job goes
    - Practicable if moving data around is simple and efficient (The GRID officially uses FTS/SRM for this)
    - Eventually doing static data/site partitions, or putting in a site everything which will be needed by the next processing round made local
      - Quite unpractical but inelegantly doable
    - In its extreme form the data files are copied locally to the WN
- Or:
  - Send the jobs to the data if possible
    - Without fully enforcing the proximity
    - The bulk of the load will be in the LAN
  - And then access directly the data, Web-like.
    - Very recent technological possibility (historically was quite inefficient for random data processing through WAN)
    - Better for common data sets accessed by many jobs
      - In general, for things which are unpractical to replicate everywhere

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Where to put the data?

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- As an example, ALICE chose to:
  - The data access uses a unique file-system-like technology, called XROOTD
  - (Sub)jobs are sent (automatically) to the site which hosts the main data file(s) they need in its Storage Element (SE)
  - Conditions data (many complex files needed by many jobs, always the same for a run) are accessed via WAN from 1-2 SEs accessible from everywhere

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LFNs and PFNs

- Logical File Name: a filename as it is seen by the application
- Physical File Name: the filename as it is physically stored
  - E.g. with the mount point prefix before
  - Or a completely different file name
- It's a powerful idea to implement location transparency
- This distinction can make things easier or difficult.
  - A simple rule (e.g. a local directory prefix) can make it easier to aggregate servers into clusters, exposing a common name space
  - An older idea was to completely detach them, and assign a number as a PFN
  - Doing so, the association pieces must be kept in a DB

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The "Line of Fire"

- A very common pitfall: "we can translate all the requests towards the SE as they come, so we can implement a relational DB-based system which spreads the load through N data servers"
  - In practice, it stores the exact location(s) of each file
  - It may work in principle, but it may be as demanding as serving the data. Very difficult to accommodate in sites with varying service levels.
  - Also, such an external system cannot reflect unexpected changes (e.g. a broken disk)

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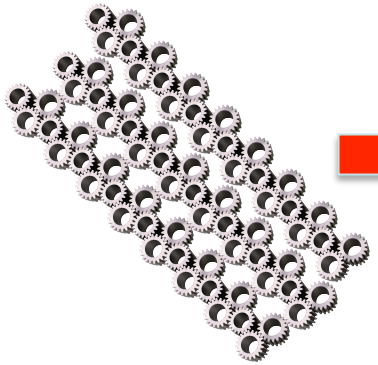
The "Line of Fire"

- Designs, informally, the architectural position in the front of a storage element, directly exposed to the load coming from the processing jobs
  - Very delicate position where to put any system
  - The transaction rate (open) can get up to 2-3K per second per site
  - Eventually, the load will accumulate until…



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Xrootd and Scalla

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- In 2002 there was the need of a data access system providing basically:
  - "Indefinite" scaling possibility
  - Maniacally efficient use of the hardware
  - Accommodate thousands of clients per server
  - Great interoperability/customization possibilities
- In the default config it implements a non-transactional distributed file system
  - P2P elements to aggregate up to 262K servers through LAN/WAN
  - Sacrifies a few POSIX constraints (e.g. distributed locks) to get scalability and performance
  - Protocol and client/server designed for high performance in data access
  - Not linked to a particular data format
    - Thus matching very well the ROOT requirements

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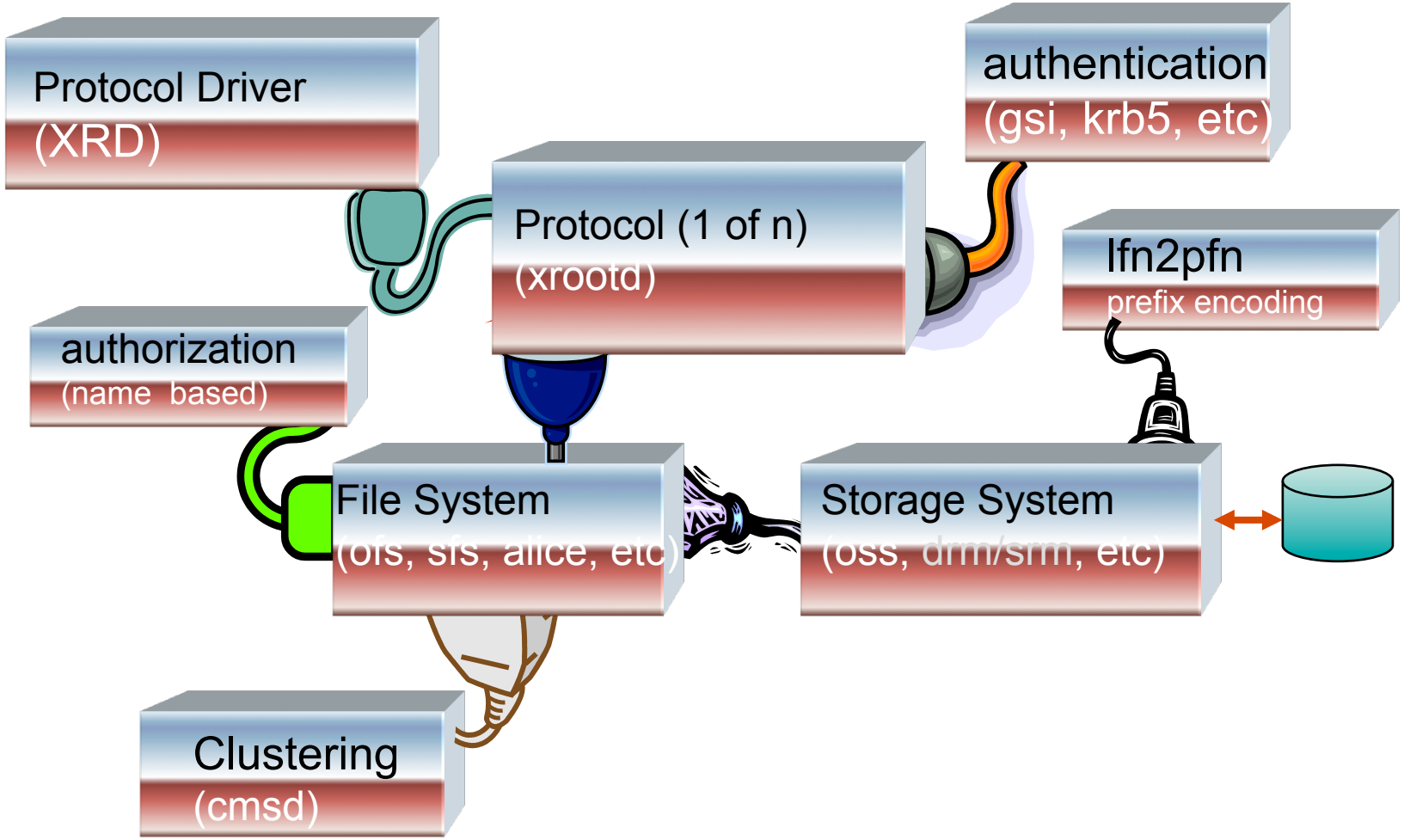
Plugins



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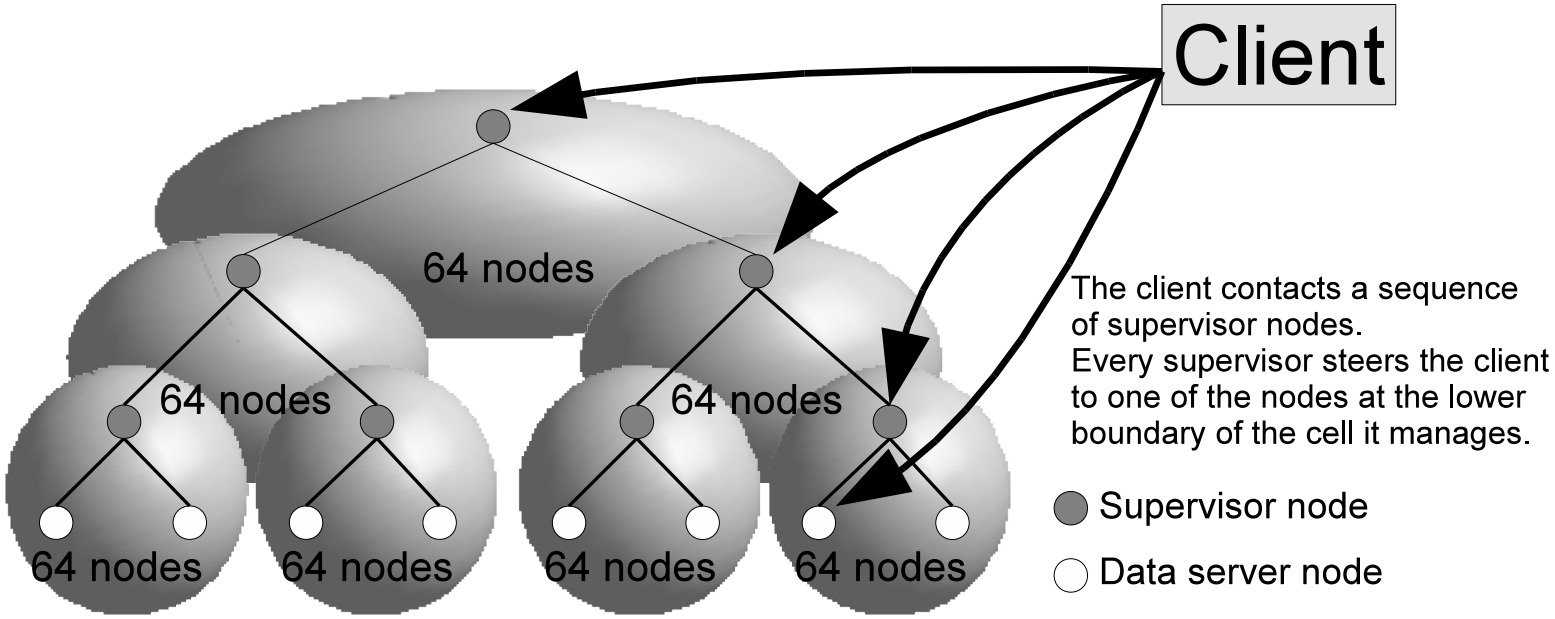
Cells



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Performance in data access

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- The Scalla/xrootd project puts great emphasis in performance. Some items:
  - Asynchronous requests (can transfer while the app computes)
  - Optimized vectored reads support (can aggregate efficiently many chunks in one interaction)
  - Exploits the ‘hints’ of the analysis framework to annihilate the network latency
    - And reduce the impact of the disks’ one by a big factor
  - Allows random-access-based data access through high latency WANs

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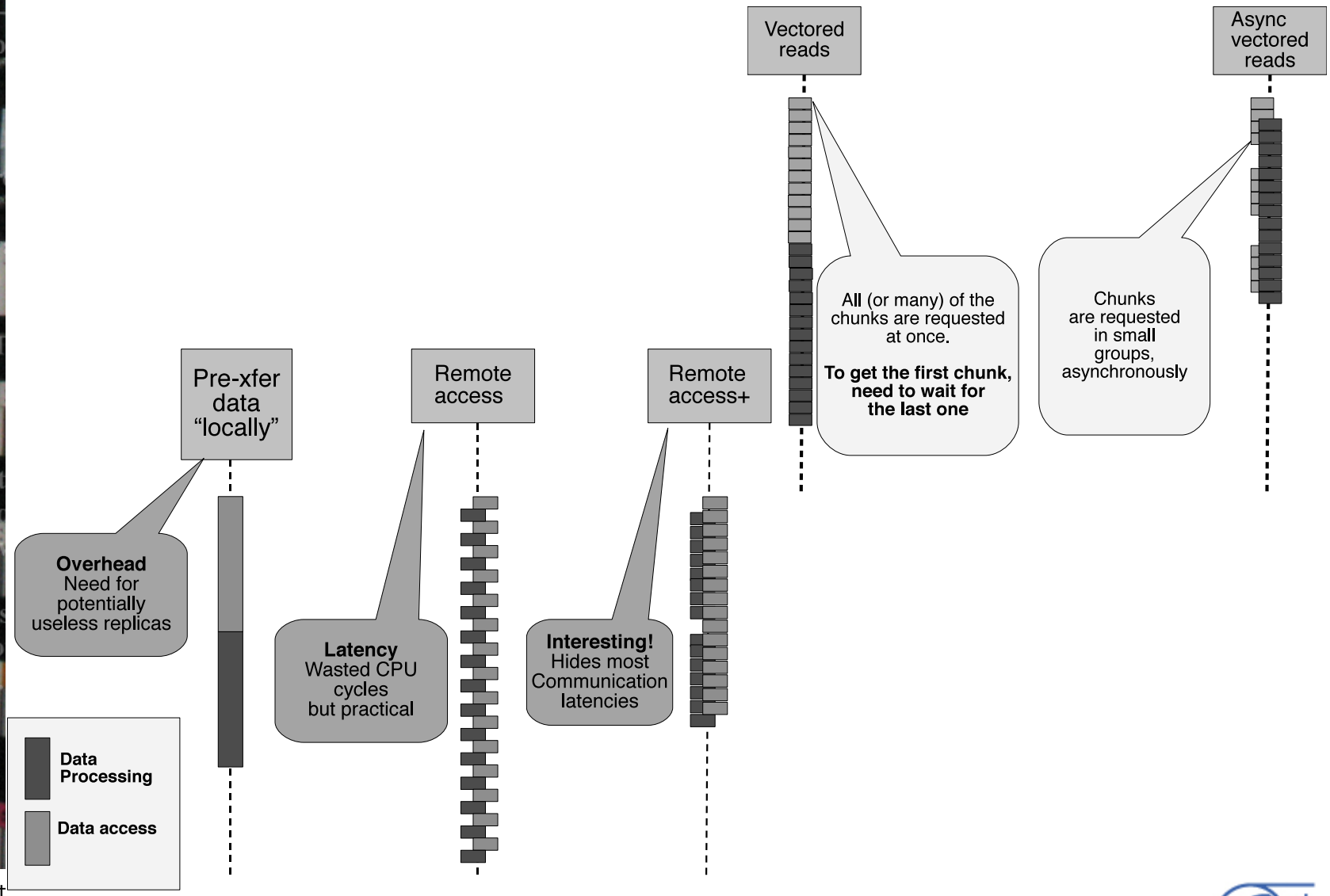
Access strategies



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WANs are difficult

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- In WANs each client/server response comes much later
  - E.g. 180ms later
- With well tuned WANs one needs apps and tools built with WANs in mind
  - Otherwise they are walls impossible to climb
    - I.e. VERY bad performance… unusable
  - Bulk xfer apps are easy (gridftp, xrdcp, fdt, etc.)
  - There are more interesting use cases, and much more benefit to get
- ROOT has the right things in it
    - If used in the right way

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What can we do

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- Basically, with an XROOTD-based frontend we can do 2 things via WAN:
  - Access remote data
  - Aggregate remote storages
    - Build an unique storage pool with subclusters in different sites
    - No practical size limits, up to 262K servers in theory
    - No third-party SW needed
    - So, we don't need to know in advance where a file is…
    - We just need to know which is the file we need
- There are pitfalls and things to consider
  - But a great benefit to get as well
  - Let's see what's possible and some of the new ideas

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Exercise

- Caltech machinery: 10Gb network
- Client and server (super-well tuned)
  - Selectable latency:
    - ~0.1ms = super-fast LAN
    - ~180ms = client here, server in California
      - (almost a worst case for WAN access)
- Various tests:
  - Populate a 30GB repo, read it back
  - Draw various histograms
    - Much heavier than the normal, to make it measurable
    - From a minimal access to the whole files
    - Putting heavy calcs on the read data
    - Up to reading and computing everything
      - Analysis-like behaviour
  - Write a big output (~600M) from ROOT

Thanks to Iosif Legrand and Ramiro Voicu

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Exercise

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- This is not a “Bandwidth race”
  - The goal is not to fill the 10Gb bandwidth
    - Others are interested in that, and do it very well
- We wanted to see:
  - Can we use all this to live better with data?
  - How does a normal task perform in LAN/WAN?
    - In a measurable and stable WAN environment
- Local disk vs XROOTD vs HTTP (Apache2)
  - Why HTTP? Because it is just the most difficult opponent:
    - Efficient (LAN+WAN) and lightweight
    - No bandwidth waste *
    - Very robust server (but not enough OK for HEP data mgmt)
    - Well integrated in ROOT, works well (except writes, not supported)

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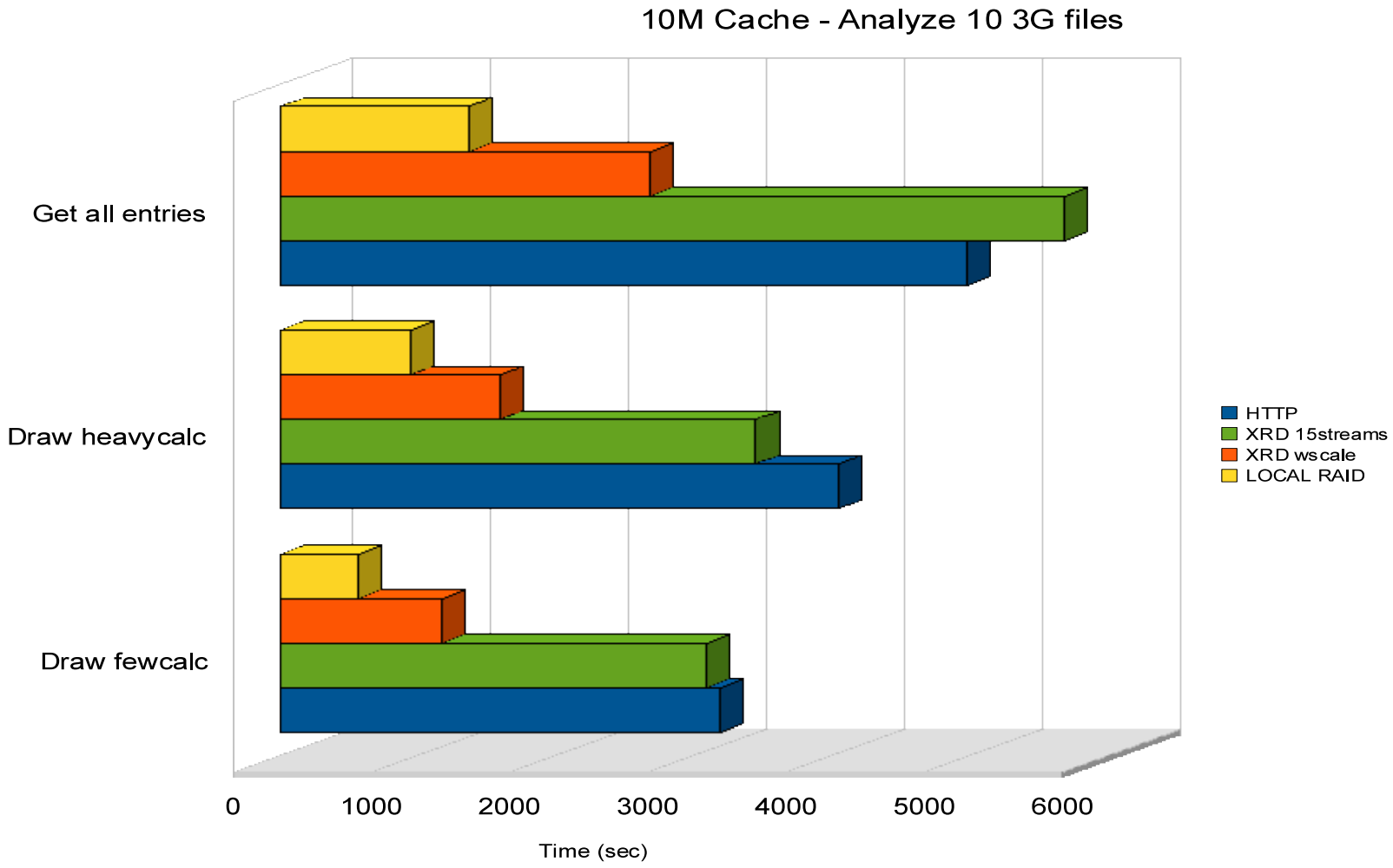
** See the talk about gpfs/xrootd (on Thu) and the Lustre analysis by A.Peters (ACAT08)*

10Gb WAN 180ms Analysis



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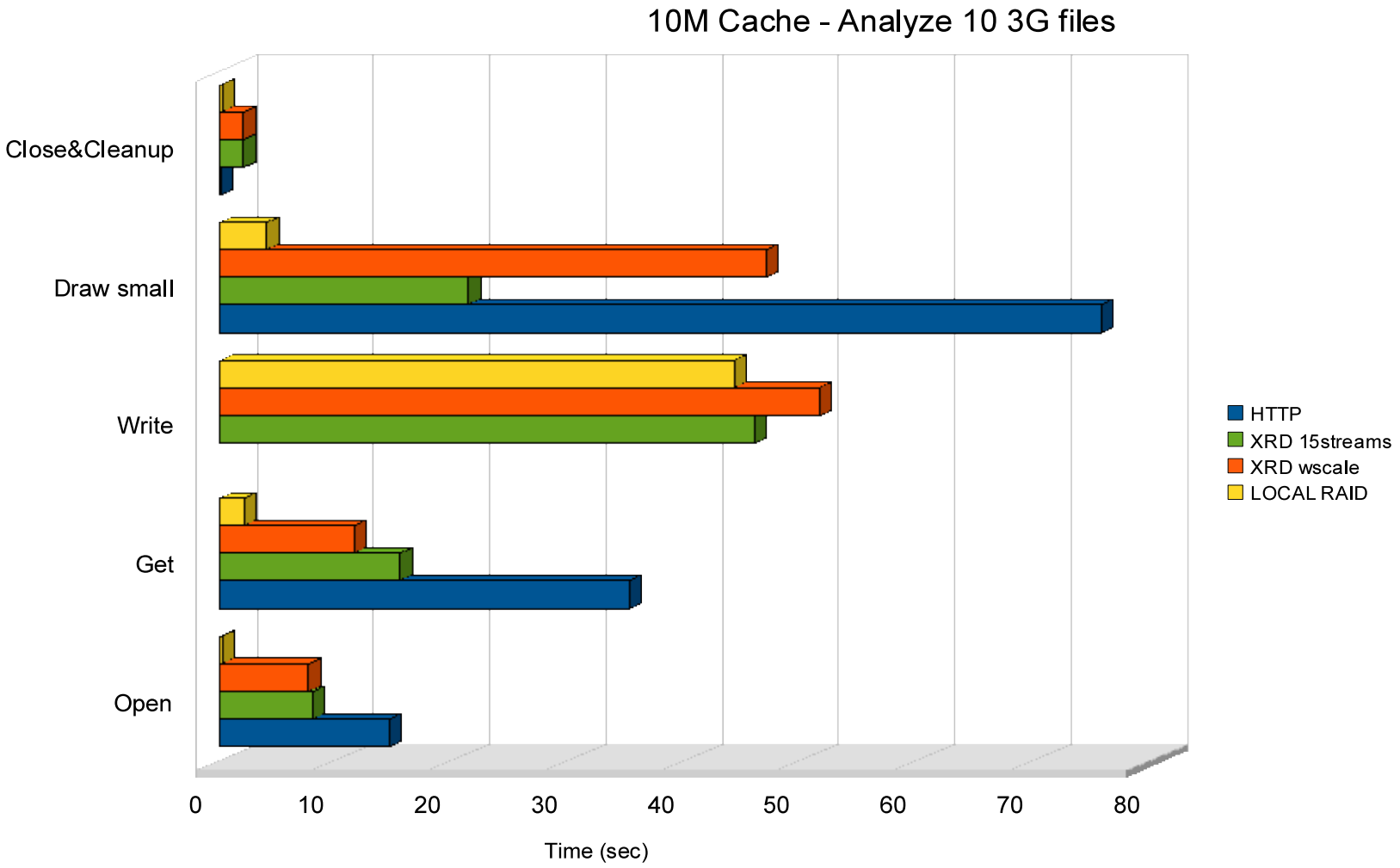
10Gb WAN 180ms Analysis



An estimation of Overheads and write performance

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Comments

- Things look quite interesting
  - BTW same order of magnitude than a local RAID disk (and who has a RAID in the laptop?)
  - Writing gets really a boost
    - Aren't job outputs written that way sometimes?
    - Even with Tfile::Cp
- We have to remember that it's a worst-case
  - Very far repository
  - Much more data than a personal histo or an analysis debug (who's drawing 30GB personal histograms? If you do, then the grid is probably a better choice.)
  - Also, since then, the performance of the sw increased further by a big factor

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Comments

- As always, this is not supposed to substitute a good local storage cluster
  - But can be a good thing for:
    - Interactive life, multicore laptops
    - Saving the life of a job landed in a place where its input is not present
    - Federating relatively close sites…
      - E.g. one has the storage, the other has the WNs
    - An user willing to debug its analysis code locally
      - Without copying all the repo locally
    - Whatever could come to the mind of a WWW user

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A nice example

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- ALICE conditions data repository
  - Regular ROOT files annotated in the AliEn catalogue
    - Populated from various online DBs and runtime detector tasks
    - Nothing strange
  - Primary copy on xrootd storage servers at CERN (5x, 30 TB total)
  - Accessed directly by all MC and reconstruction jobs on the Grid
    - Up to 12Kjobs, Up to 6-8K constant connections
    - Directly means no pre-copy, i.e. very byte-efficient

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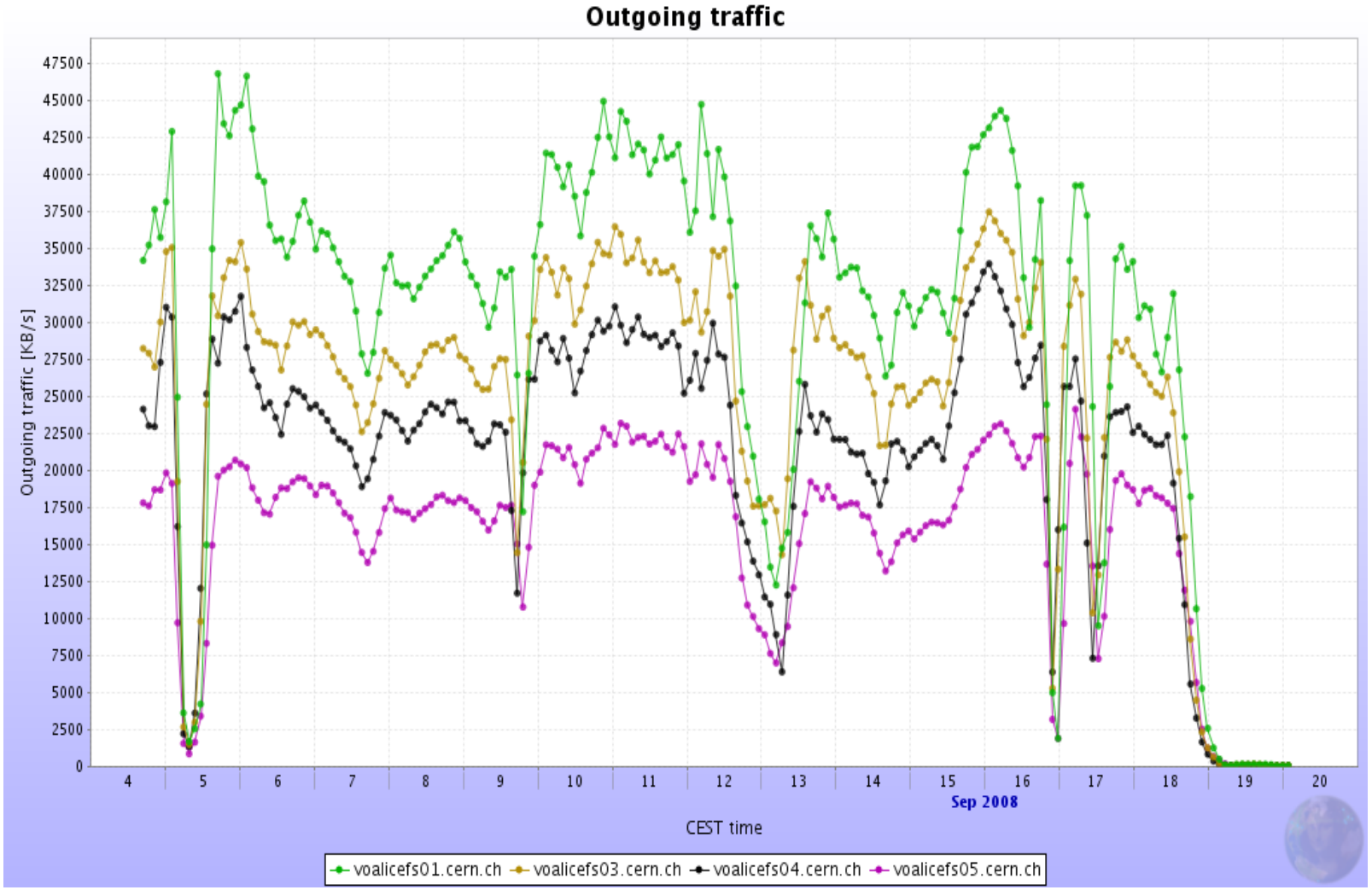
A nice example



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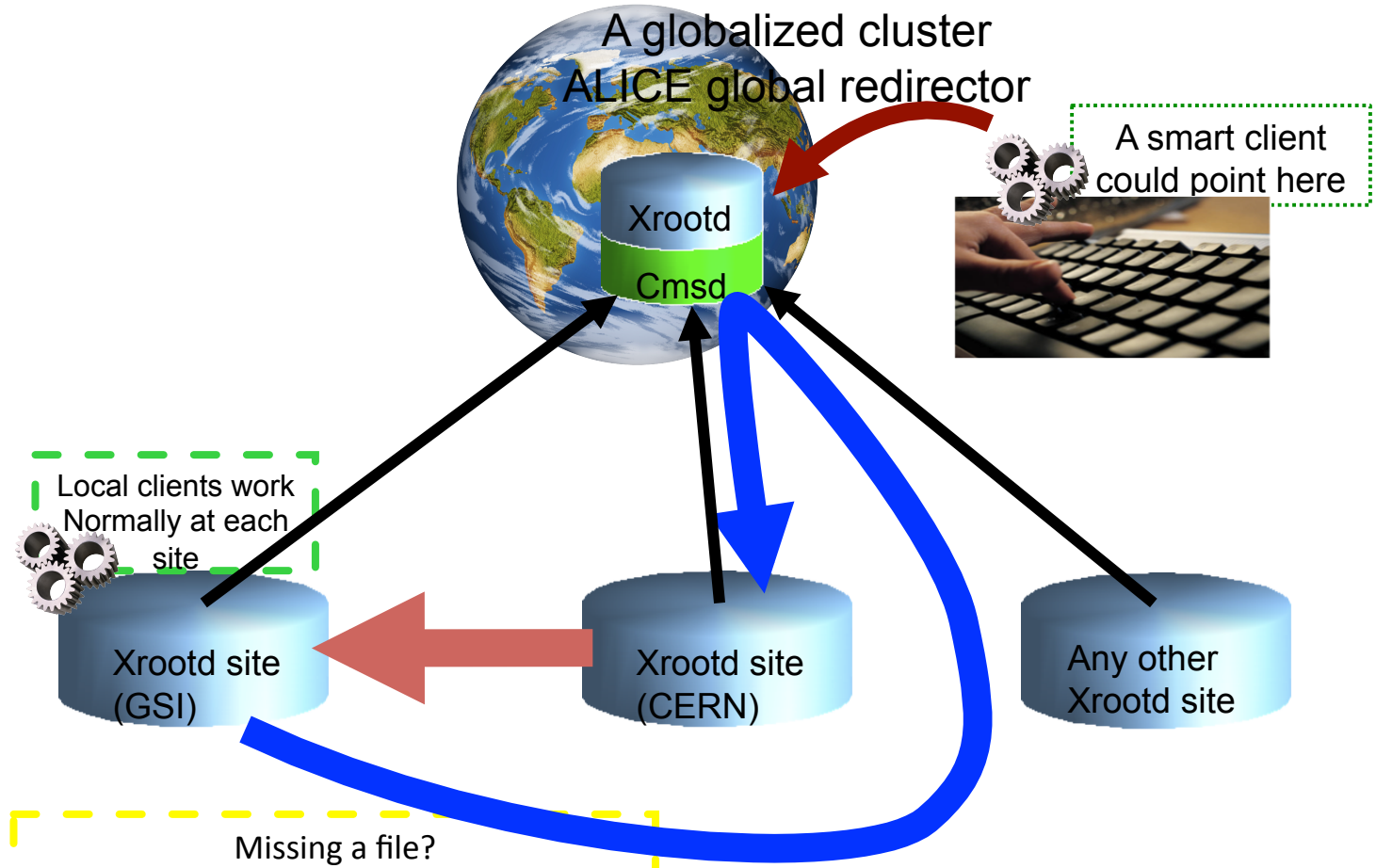
More than Globalization: The VMSS



Virtual
Mass
Storage
System
… built on data Globalization

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Conclusion (1/3)

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- Many things are possible
  - E.g. solving the “conditions data” problem was a breakthrough for Alice
    - It would be nice to use the globalization to lighten the File Catalog
      - And use it more as a metadata catalog
- Technologically it’s satisfactory
  - But not ended here, there are new possible things, like e.g.
    - Torrent-like *Extreme copy*
      - To boost data movements also in difficult sites
    - Mounting locally a globalized WAN Xrootd metacluster
      - As a local file system using the XCFS tools

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Conclusion (2/3)

- On the level of the data access framework (ROOT) many things improve every day
  - E.g. how to generate a more “disk-friendly” load to avoid inefficiencies
  - All the improvements bring us closer to the possibility of exploiting forms of “interactive access” to the applications
    - That would mean an evolution from the current “batch system” approach
    - Some projects are aiming for that (e.g. PROOF)
    - That means also having interactive access to the data
    - The massive deployment of these newer technologies could be the real challenge for the next years

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Conclusion (3/3)

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- "Large DBs on the GRID" …
  - It should be more clear that we are talking about complex distributed systems which interleave:
    - Big and structured high-perf data repositories
    - Complex metadata
    - Distributed computing infrastructures
  - Hence their characteristics interleave
    - Right now the best answer IN HEP is to complement them
    - Use conventional DBs for the metadata and ev. For the coordination
    - Use Web-like direct access for the data, with efficient protocols
    - Make the applications able to exploit the modern HW
    - Organise storage and job submission in order to reduce the distance between a job and its primary source of data
      - Without heading for super-complex solutions just in order to enforce it
    - Organize the effort in order to contain the overall complexity

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Thank you!

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