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Centro Nacional de Supercomputación

User Best Practices and Results on MN5

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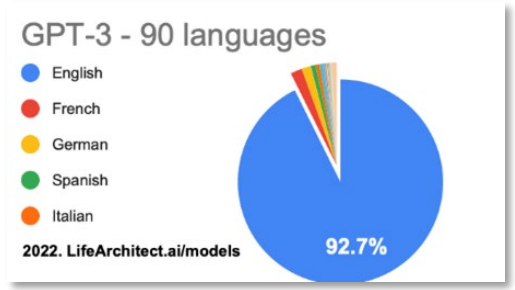
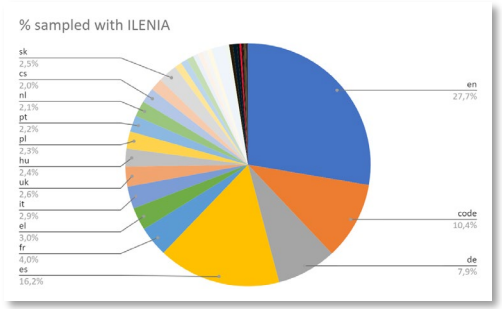
Context and motivation

- Large Language Models (LLMs), such as OpenAI's GPT, Google's Gemini, and Meta's LLaMA, are trained on massive amounts of text data **primarily in English**, limiting their performance in other languages.
  - Performance of these LLMs for languages with a “weak” or “moderate” technology support, is always significantly weaker than in English.
- The field of generative AI is largely dominated by American technology giants.
  - Europe is far behind.
- Although most LLMs are 'weight open', they are far from being truly open source.
  - Often the code is not open and there is little information on training data.
- New European AI regulations impose levels of transparency and traceability of data that require an adequate approach.
- In response to this situation, three national projects (AINA, ILENIA and Modelos) were created to develop models and resources for the languages of Spain.

Towards truly multilingual EU LLMs





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MareNostrum 5

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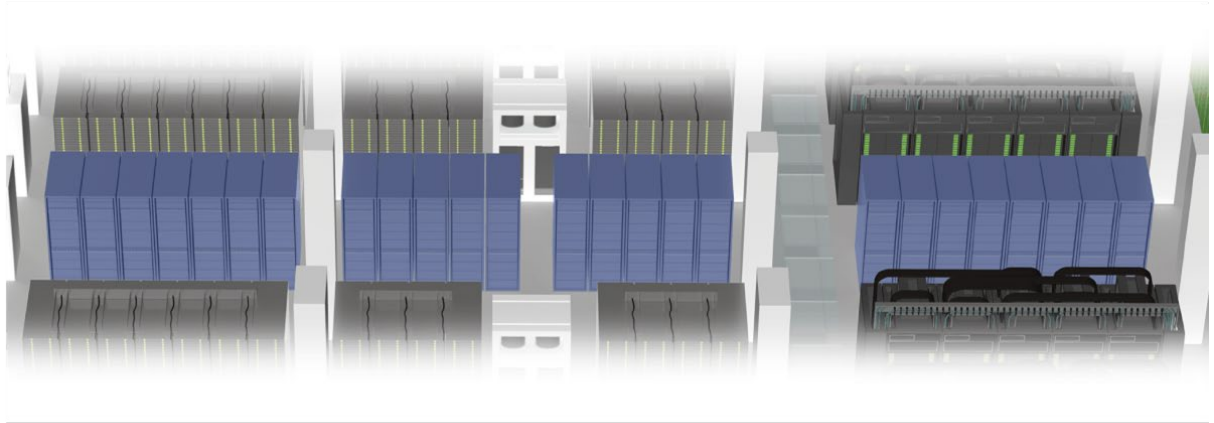
MareNostrum 5: Storage

The results of the calculations carried out are stored in 25 racks, each containing 816 18-terabyte hard drives.

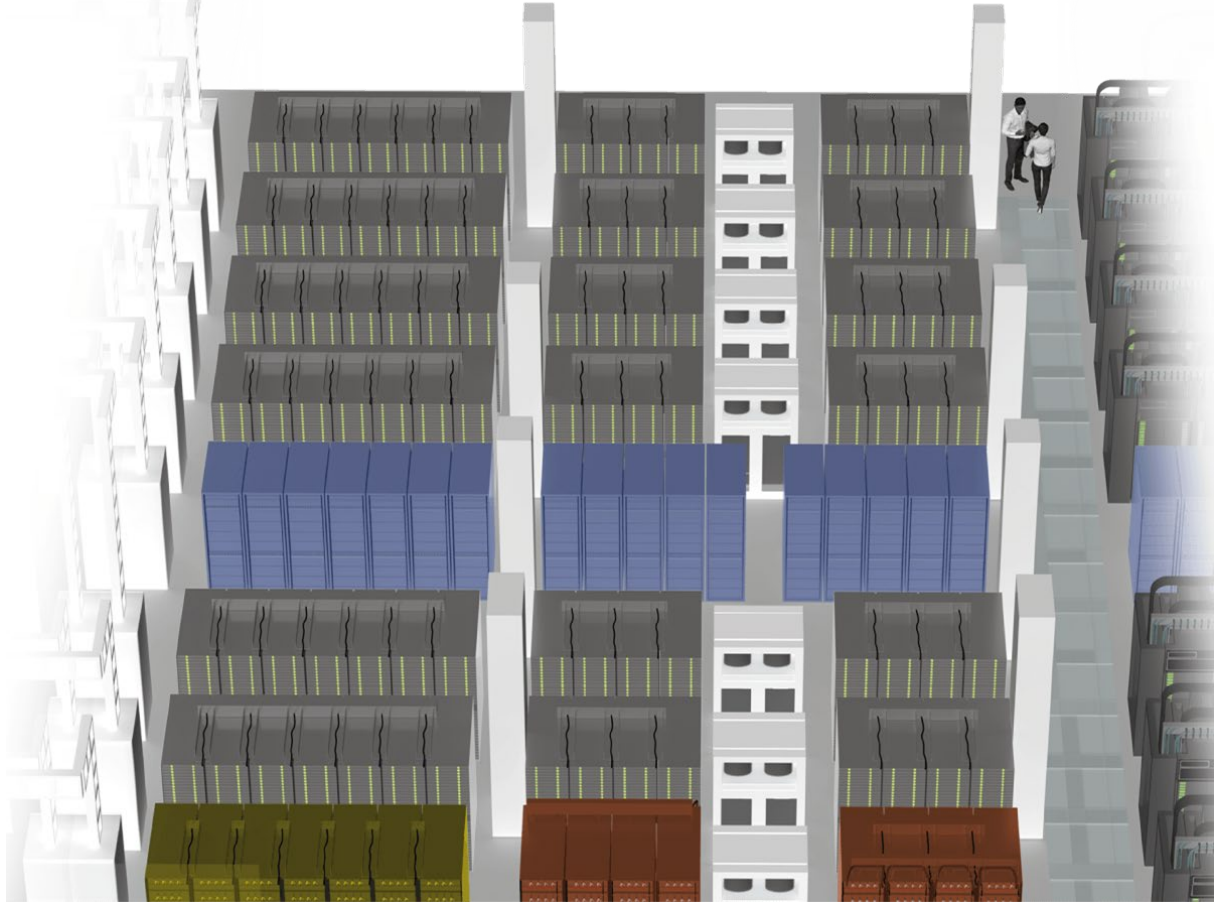
Total net space: 248,000 TB.



They could store 1,280 copies of every book catalogued throughout history.

MareNostrum 5: General Purpose Partition

To help solve major scientific problems. 90 racks, 6,480 nodes and 12,960 chips.



MareNostrum 5: Accelerated Partition

■ 35 racks, 1,120 nodes and 6,720 chips
(4,480 of them, accelerated).

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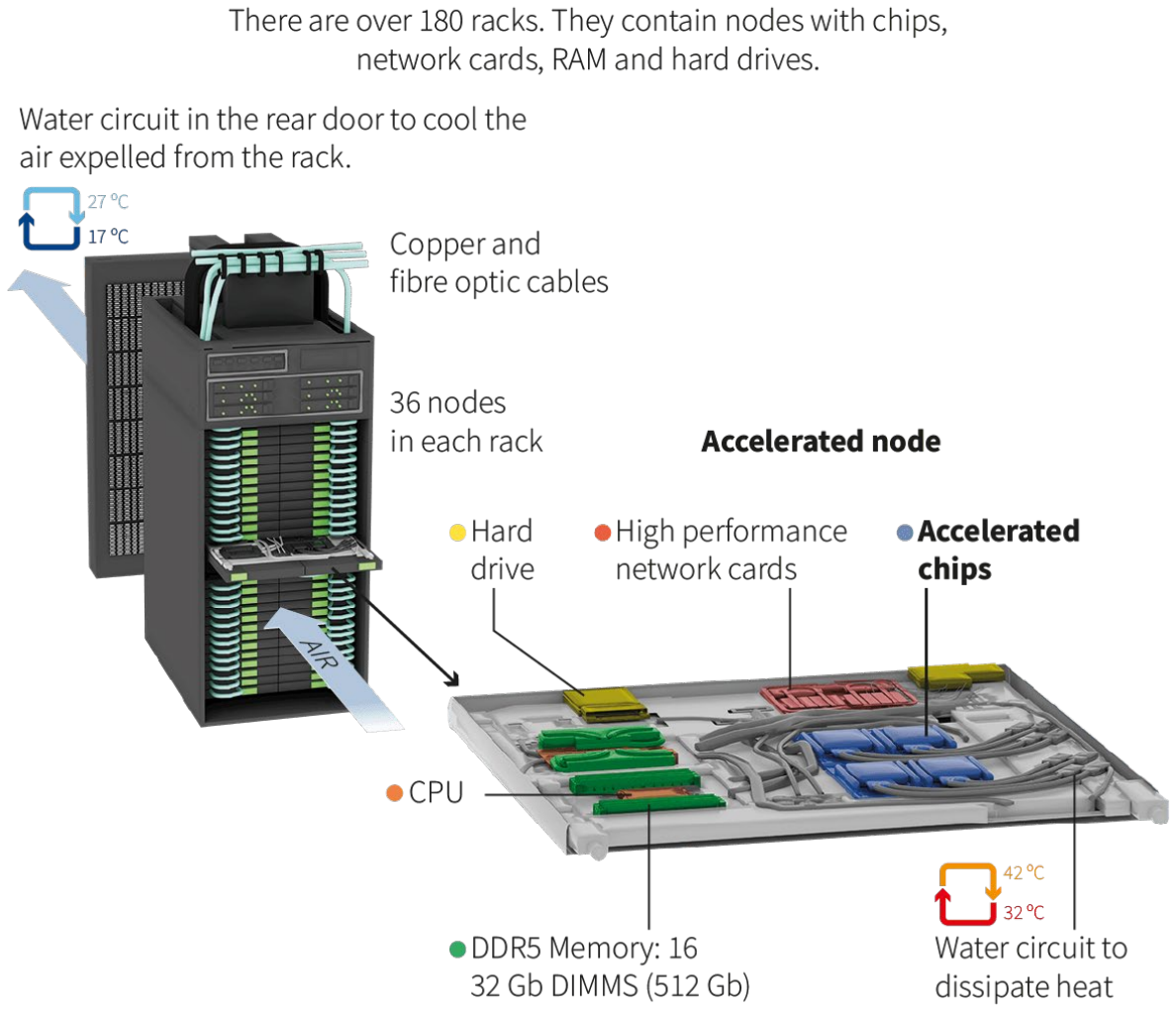
MareNostrum 5: H100 64GB GPUs



What is 3D parallelism?

Objectives

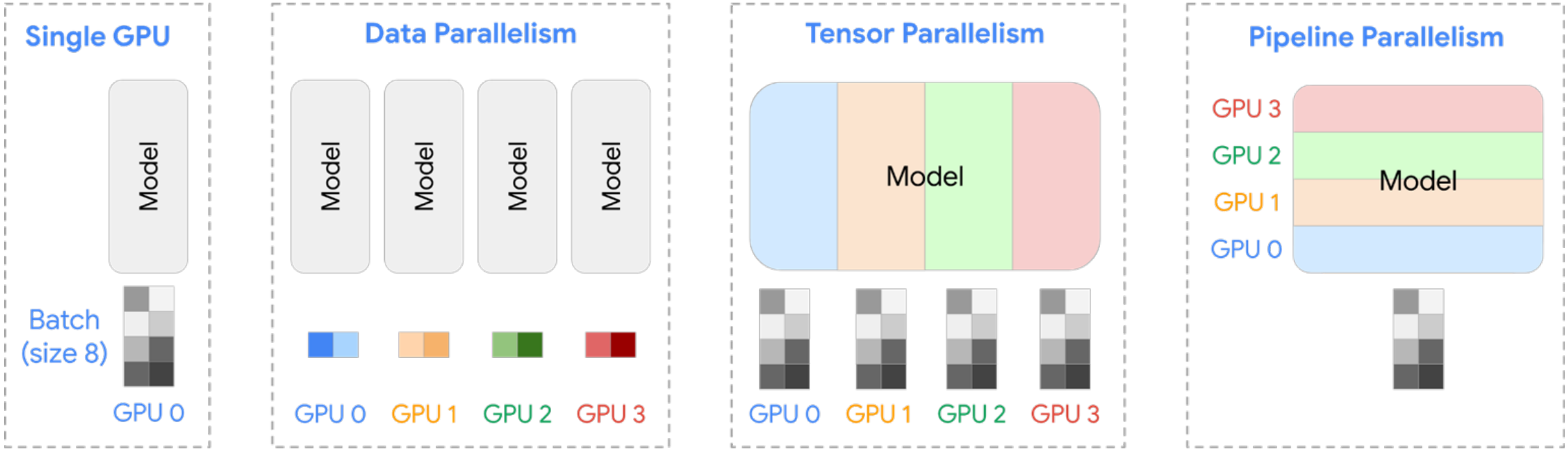
- Reduce the training time of large deep learning models.
- Allow for the training of larger models.
- Optimize hardware utilization.

Definition

3D parallelism training tackles these objectives with a combination of three methods:

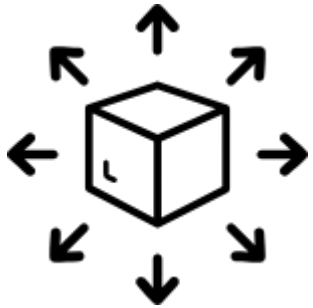
- Tensor Parallelism.
- Pipeline Parallelism.
- Data Parallelism.

What is 3D parallelism?



Typical Bottlenecks

- **Communication Latency.** The communication between nodes causes latency in the training that must be studied and optimized.
- **Coordination Complexity.** 3D parallelism involves intricate data partitioning and synchronization, making it challenging to implement and manage efficiently.
- **Framework Support.** Many deep learning frameworks and libraries lack robust support for 3D parallelism, limiting its usability.
- **Stability.** Larger models can exhibit spikes during pre-training, posing challenges for maintaining stable and consistent training progress.



Data, Pipeline and Tensor Parallelism

- Lower model parallelism does not always imply better performance.
  - Increased model parallelism reduce data parallelism, which in turn can improve the bottlenecks derived from the communication latency associated with it.

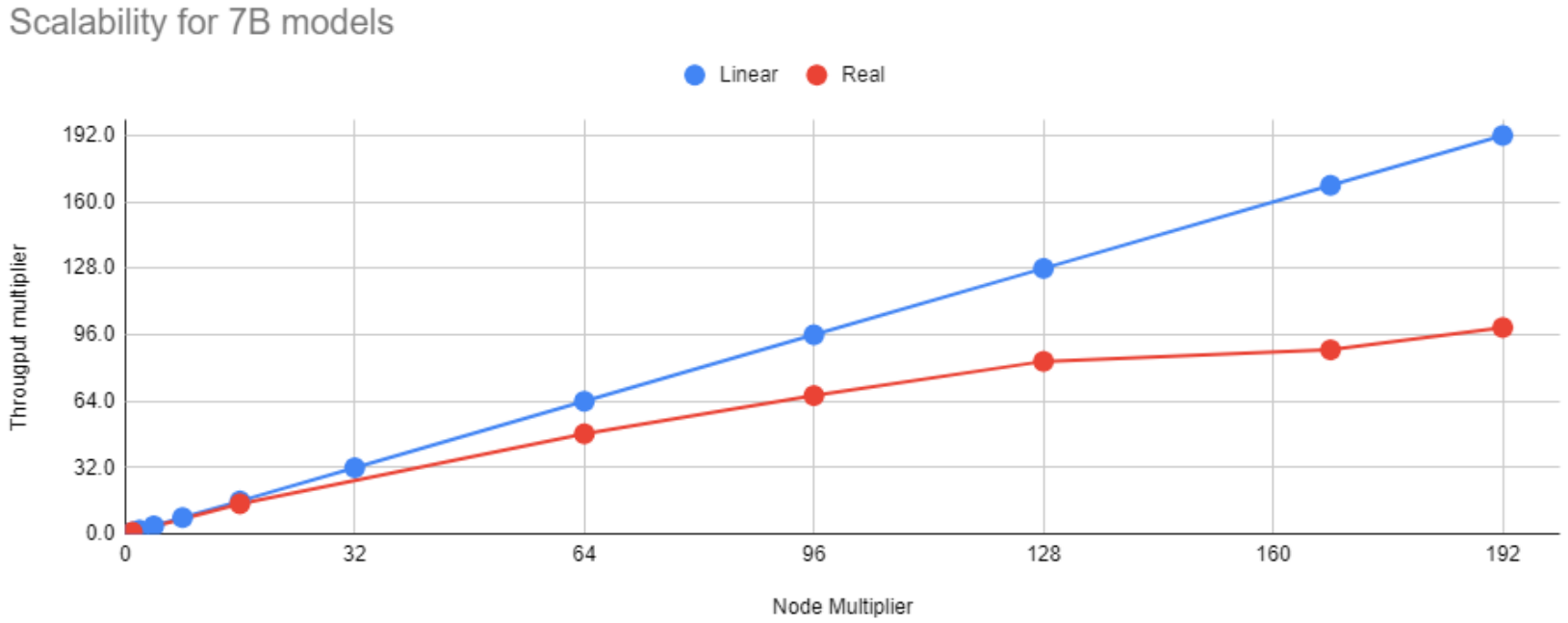
- We could not find a single run where FP8 was better than BF16 in performance, which indicates that the computation was not the main bottleneck.

- NeMo framework proved to be more optimal than GPT-NeoX.

jobid	NPARAMS(B)	world	gbs	mbs	tp	pp	dp	bits	TFlops/GPU
1561797	7220000000	512	1024	4	4	1	128	bf16	225.49
1549683	7200000000	512	1152	3	4	1	128	bf16	219.48
1549657	7200000000	512	1024	4	4	1	128	bf16	217.33
1542017	7200000000	512	1024	2	2	1	256	fp8	209.12
1561796	7220000000	512	1024	2	4	1	128	bf16	207.92
1561803	7220000000	512	1152	3	4	1	128	bf16	207.62
1549632	7200000000	512	1024	2	2	1	256	bf16	206.62

Scalability

- Scalability is not linear, and the performance per GPU decreases as we increase the number of nodes.
- The larger the model, the better it scales to a large number of nodes.
    - For the 7B model, going from 64 nodes to 128 nodes results in a throughput increase of 86%, but going from 64 nodes to 192 nodes, this increase is reduced to 68%.
    - For the 40B model, scaling from 256 nodes to 512 nodes still yields an increase of 73%.



Objectives & Roadmap

- **OBJECTIVE:** To generate a family of decoder models trained with a large volume of high quality, legal data, with a good multilingual composition and representation of different domains. We have collected a corpus of 10 Trillion tokens on 35 languages (+code), cleaned & deduplicated with a focus on Spanish:
  - **First stage: Train 2B, 7B & 40B models.**
  - Second stage: MoE and Multimodal variants.

- **ROADMAP:**
  1. Debugging phase of frameworks and corresponding bug fixing. **DONE**
  2. Ensure correct operation of critical functions such as: checkpoint copying; stopping and resuming of training; de-scaling of models (e.g. downscaling from 128 to 64 nodes, and still training correctly); log copying, ... **DONE**
  3. Performance testing, looking for the best hyper parameter settings to get the best performance. **DONE**
  4. Scalability tests, to check that the performance obtained in (3) is not lost by increasing nodes and/or model size. **DONE**
  5. Train the models! **DONE**/**In progress**
  6. Evaluate and release the models. **DONE**/**In progress**

Best Practices I

- Intended use of the Accelerated Partition (ACC) vs General Partition (GPP):
  - Bear in mind the specific use of each queue. If only CPUs are needed, DO NOT send to ACC.
- DO NOT run compute-intensive jobs in a login node to avoid overloading it.
- When sending a job to the queue, DO NOT ask for more resources than necessary.
  - This applies to both the number of nodes and the duration of the job.
- Use the debug queue for short jobs, very useful for rapid tests.
- With great power comes great responsibility: DO NOT abuse salloc.

Best Practices II

- Edit your ***.bashrc*** file to make sure that newly created files have the right permissions by default.
- To copy or move large files, consider using the ***dtcp***, ***dtmv***, and ***dtrsync*** commands.
- Use symbolic links to avoid duplicating unnecessary data.
- Increase your data loading speed by using the local storage in each node.
- Data management: The different **filesystems** and how to use each of them.
  - **Home**: Personal finals.
  - **Projects**: Projects data, environment, final results.
  - **Scratch**: Temporal files, such as checkpoint checkpoint or intermediate data.
  - **Tapes**: Long-term storage for data that is not expected to be processed in the short-medium term.

Tips for Users I

- Useful ***slurm*** commands:
  - sbatch: Submit a batch script to slurm.
  - squeue: View job information.
  - scancel: Cancel a slurm job.
  - salloc: Allocate nodes to work interactively. Use with caution, and DO NOT forget to release the nodes after finishing.
  - scontrol: View of modify slurm configuration.

- Useful ***bash*** commands:
  - htop: Process monitoring.
  - nvidia-smi: To monitor GPU usage.
  - df/du: Information about disk usage.
  - ps: Information about running processes.
  - chmod: Set and modify file permissions (set them correctly!).
  - screen/tmux: To use multiple shell sessions from a single ssh session.

Tips for Users II

- Useful ***MN5*** commands:
  - bsq_quota: Information about the available space on each file system.
    - Check regularly: If the system runs out of space (for example, due to creating checkpoints), execution will stop.
  - bsc_queues: Information about the queues available to the user.
    - Select the appropriate one, based on the number of nodes needed and the maximum duration of each queue.
    - For debugging, send shorter jobs to the debub to reduce the time in the queue.

- Create ***aliases*** in your *.bashrc* to save time when doing tasks you do frequently:
  - `alias goto_projects='cd /gpfs/projects/bsc88/'`
  - `alias myenv_load='source ~/venv/bin/activate/'`
  - `alias salloc_node='salloc -A bsc88 -q acc_bscls -n 1'`
  - `alias print_dir_structure="ls -R . | grep \":$\" | sed -e 's/:$//' -e 's/[^-][^\/]*\//--/g' -e 's/^/   /' -e 's/-/|/'"`

Good to know

- A daily backup is made from the support team:
  - Only for ***Projects*** filesystem.
  - If you accidentally delete something, you can contact them.

- Use ***alogin4*** for internet access:
  - Very useful to install libraries. Requires VPN.

- Visit the HPCPortal for job monitoring and machine stats:
  - You can share your jobs with other member of the BSC.

Tips for Scaling

- Everything that was working, suddenly, stopped working.
  - Increasing nodes does not improve performance.
  - Or worse, doubling nodes reduces performance.

- Identify what is causing the problem. Three usual suspects:
  - **GPUs**: Is your parallelization correct?
  - **CPUs**: Are some CPUs saturated?
    - If your software is not doing this correctly, you need to set the CPU affinity manually.
  - **Storage**: Can your filesystem load the necessary data fast enough?
    - Try moving the data to a faster disk: the compute nodes' local SSD disk, or even a virtual disk in RAM.
  - **Network**: Does your software manage InfiniBand correctly?
    - Each node has 4 InfinyBand lanes. Manually assign each lane to each of the GPUs (the closest one) to avoid all of them using the same.

Extra: Submitting jobs with dependency

- During the 7B training, I went on vacation for a week:
  - **You're blocking the queue.**

- Having a second job in the queue is useful, when the first fails the second will automatically resume the execution.
  - Problem 1: The second job was not dependent on the first.
  - Problem 2: They were 512 node jobs (MN5 has 1,120 nodes).
    - Since we were launching to a queue with the highest priority, slurm was trying to reserve another 512 nodes for the second job, and not letting any other jobs in.
  - Solution: Submit the jobs with dependency.

Best Practices III: Job dependencies.

- Slurm allows you to launch jobs with different dependencies on other jobs:
  - *sbatch --dependency=<type:job_id[:job_id][,type:job_id[:job_id]]> ...*

- Dependency types:
  - ***after***: Job begins once the dependency has started.
    - Useful to synchronize experiments.
  - ***afterany***: Job beings once the dependency has finished, regardless of what happened.
    - Useful for not using too many nodes at the same time with jobs that don't really depend on each other.
  - ***afternotok***: Job begins once the dependency has failed.
    - Useful for resuming jobs from a previous checkpoints.
    - Use this to submit your LLM training. Your second job will be in the queue without blocking other users.
  - **afterok**: Job begins once the dependency has completed without errors (exit code 0).
    - Useful to run a second step. For instance, to run a finetuning only after the pretraining has finished, or to run the evaluation after the finetuning.
    - Warning: Exit code 0 only indicates that there have been no errors in the execution. It does not ensure that there are no conceptual or design errors.

- Command example: *sbatch -d afternotok:3638431 launch_job_7b.sh*

One last tip

- READ the MN5 documentation:
  - https://www.bsc.es/supportkc/docs/MareNostrum5/intro/

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