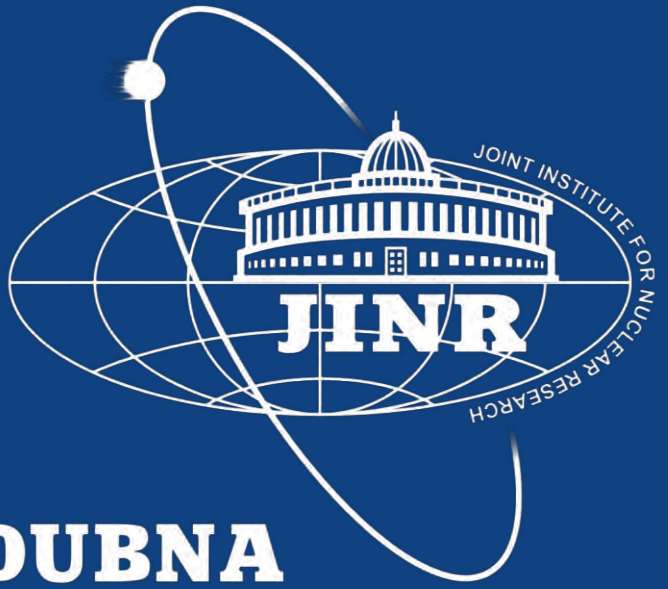
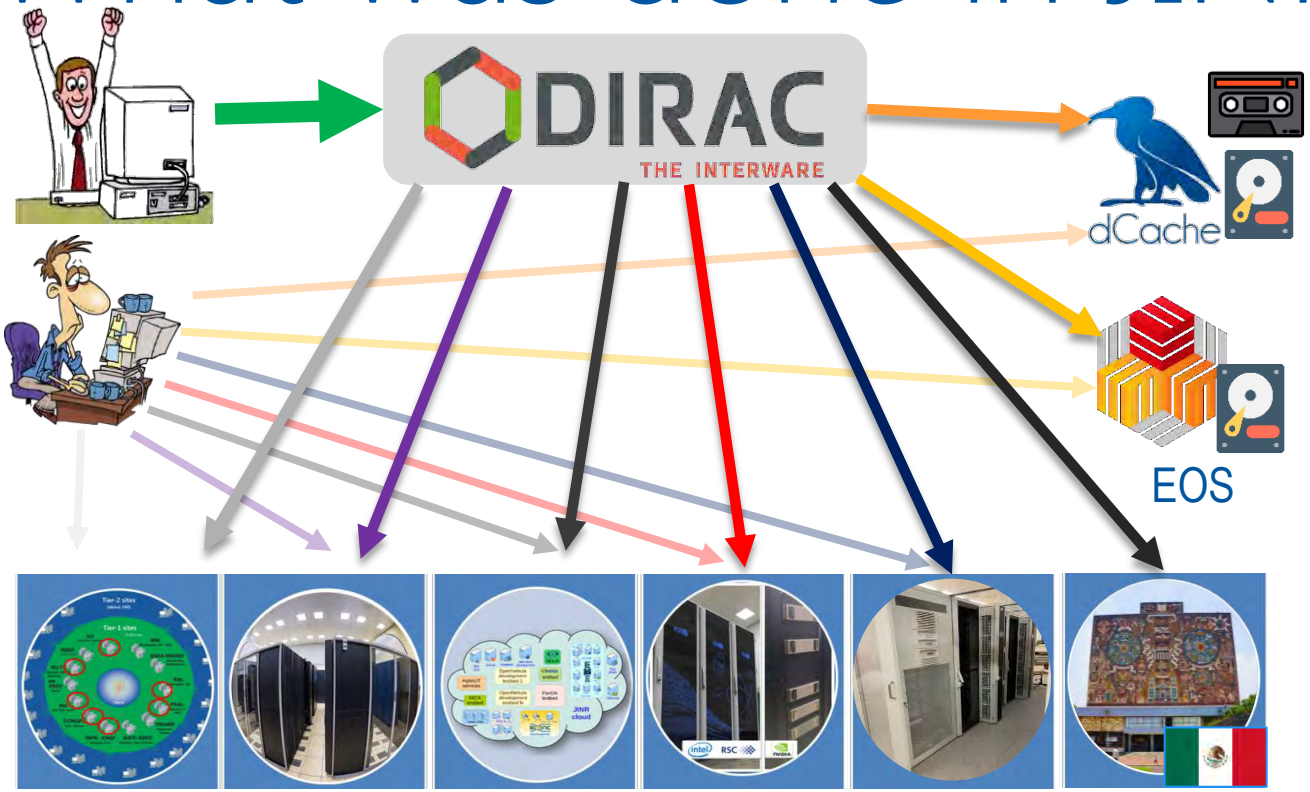

JOINT INSTITUTE FOR NUCLEAR RESEARCH
JINR
DUBNA

Simulation of job execution in distributed heterogeneous computing infrastructures

Igor Pelevanyuk, Daniel Campis

27 October 2022

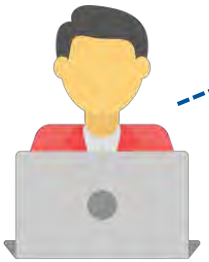
What was done in JINR



Tier-1	CICC/Tier-2	Clouds	Govorun	NICA Cluster	UNAM
Running	**Running**	**Running**	**Running**	**Running**	**Running**

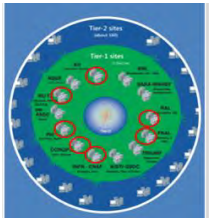
The computing resources of the JINR Multifunctional Information and Computing Complex, clouds in JINR Member-States, cluster from Mexico University were combined using the DIRAC Interware.

Workload management



Submit thousand of jobs to DIRAC Job Queue

DIRAC
THE INTERWARE


Tier-1


CICC/Tier-2

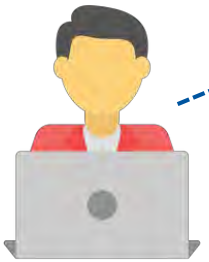

Clouds


Govorun


NICA Cluster


UNAM

Workload management



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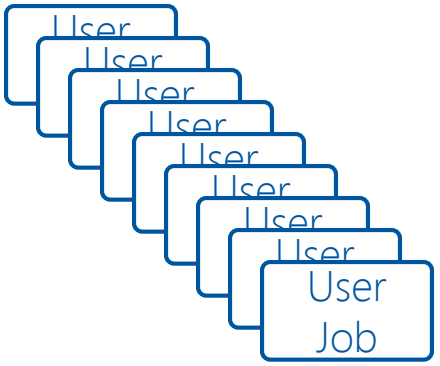
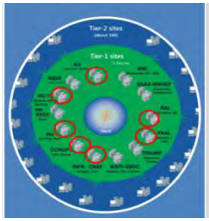


DIRAC
THE INTERWARE


Tier-1


CICC/Tier-2

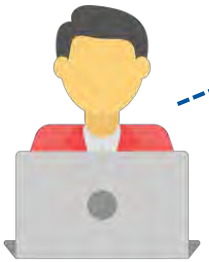

Clouds


Govorun


NICA Cluster


UNAM

Workload management



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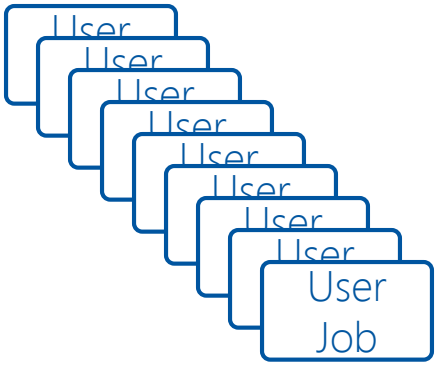
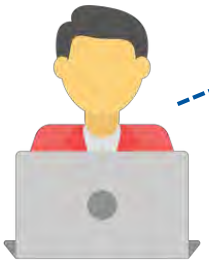


DIRAC
THE INTERWARE

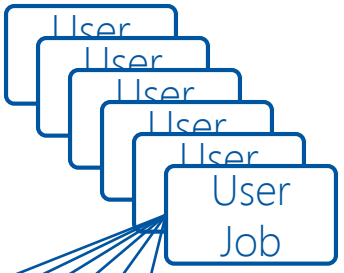
Pilot job | Pilot job | Pilot job | Pilot job | Pilot job | Pilot job

Tier-1 | CICC/Tier-2 | Clouds | Govorun | NICA Cluster | UNAM

Workload management



Submit thousand of jobs to DIRAC Job Queue



DIRAC
THE INTERWARE

Pilot job
User Job

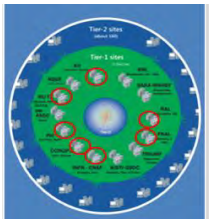
Pilot job
User Job

Pilot job
User Job

Pilot job
User Job

Pilot job
User Job

Pilot job
User Job


Tier-1


CICC/Tier-2


Clouds


Govorun

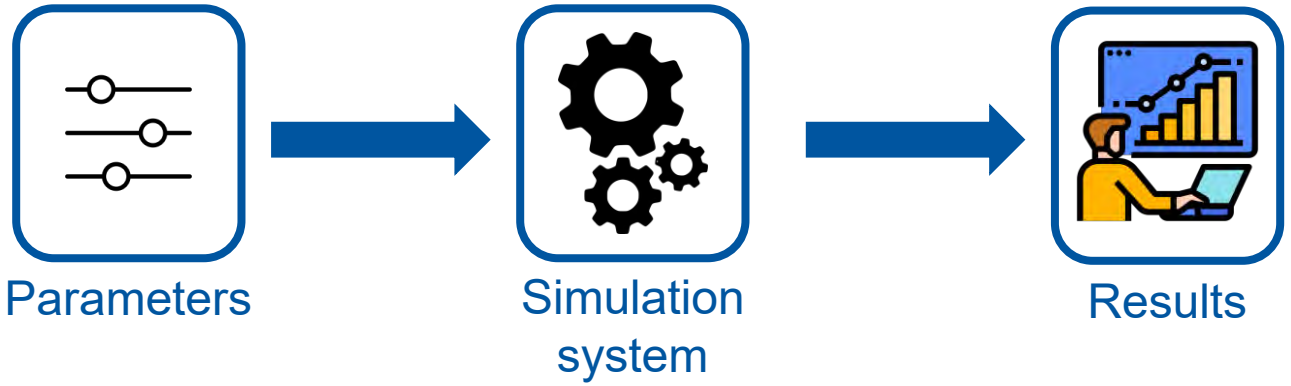

NICA Cluster


UNAM

Questions that we ask

- Are we efficient in our job execution?
  - We have no access to monitoring information on a remote computing resources
  - Even if we have monitoring, it may be spoiled by other jobs
- Can we utilize more computing resources if we would have them in our disposal?
  - It is not so difficult to submit jobs on another thousand of cores, but will network handle them efficiently?

Simulation is a solution



Parameters

Infrastructure description

- Storage elements: network speed
- Computing elements: network speed, list of servers
- Servers: cpu cores amount, cpu core performance, RAM, network

Workload description

- Jobs: amount, rate of incoming, list of tasks
- Tasks: computing or transfer tasks with cpu work or transfer amount correspondingly

Where do we get them

Infrastructure description

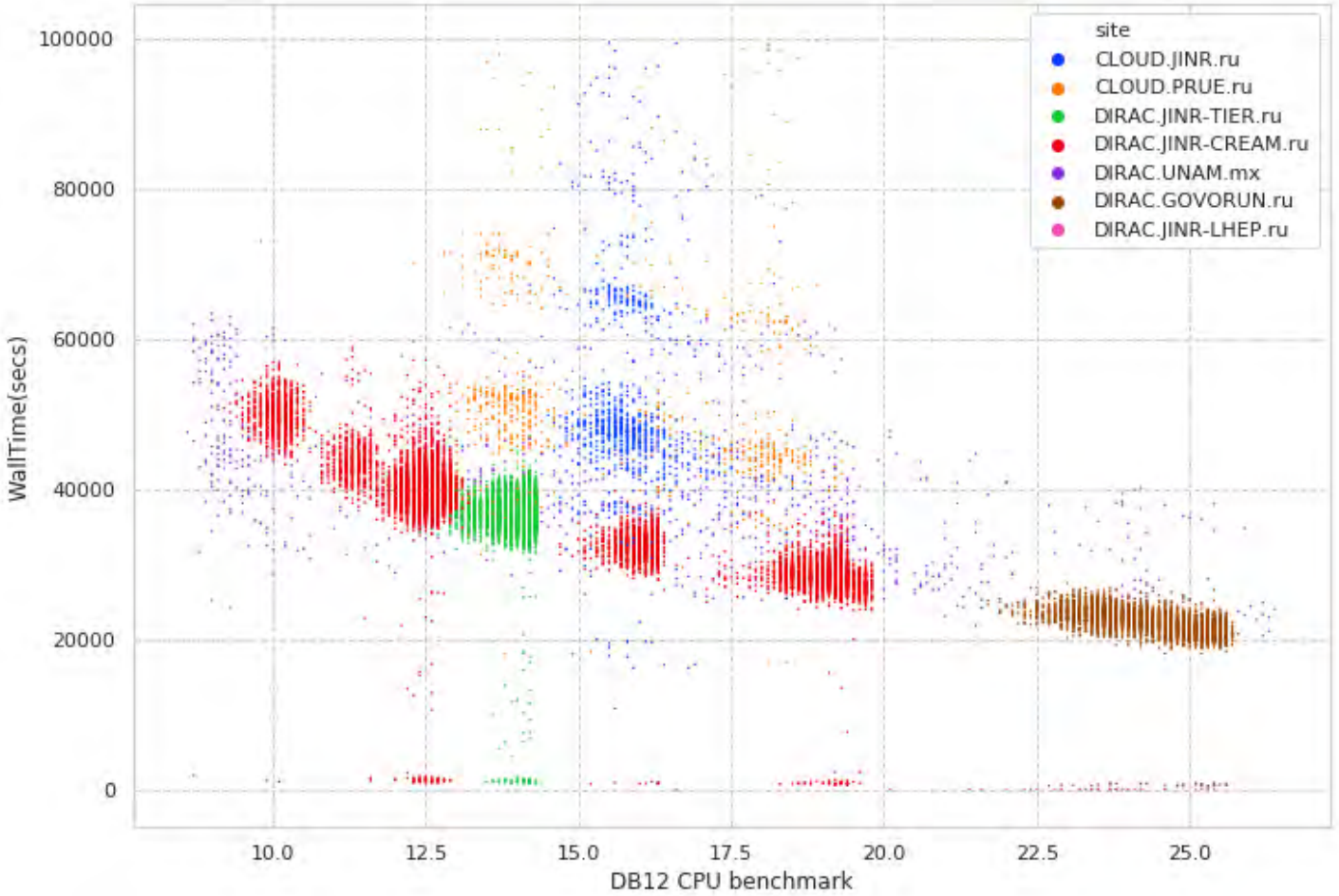
- Storage elements: network speed – transfer experiments
- Computing elements: network speed, list of servers - transfer experiments + accounting
- Servers: cpu cores amount, cpu core performance, RAM, network – network configuration + accounting

Workload description

- Jobs: amount, rate of incoming, list of tasks
- Tasks: computing or transfer tasks with cpu work(in DB12 second) or transfer amount(in bytes) correspondingly

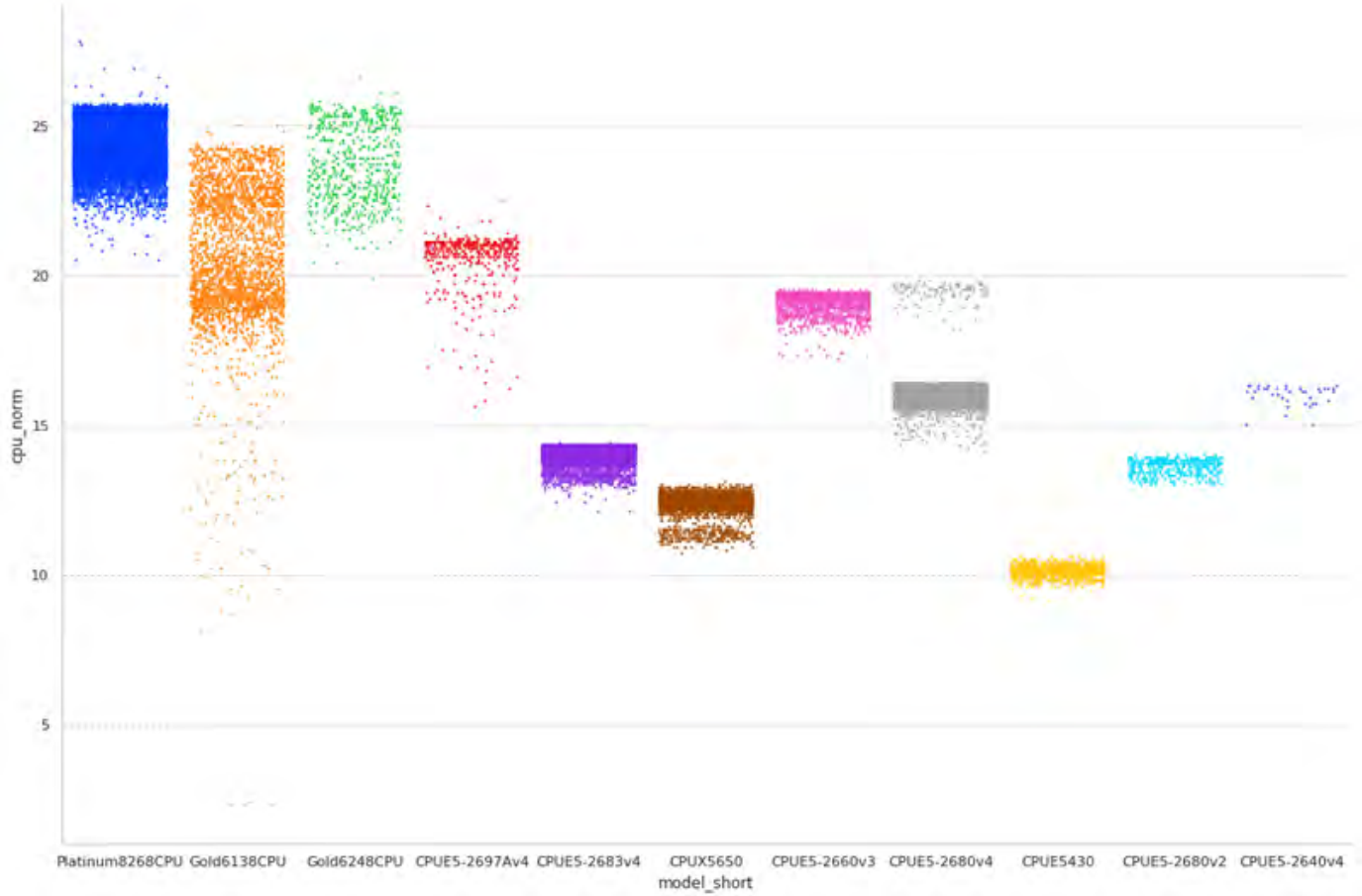
These values may be received either from specialist or from user job monitoring.

Cluster configuration



Igor Pelevanyuk, **"Performance evaluation of computing resources with DIRAC interware",** AIP Conference Proceedings 2377, 040006 (2021) https://doi.org/10.1063/5.0064778

CPU performance



Igor Pelevanyuk, **"Performance evaluation of computing resources with DIRAC interware",** AIP Conference Proceedings 2377, 040006 (2021) https://doi.org/10.1063/5.0064778

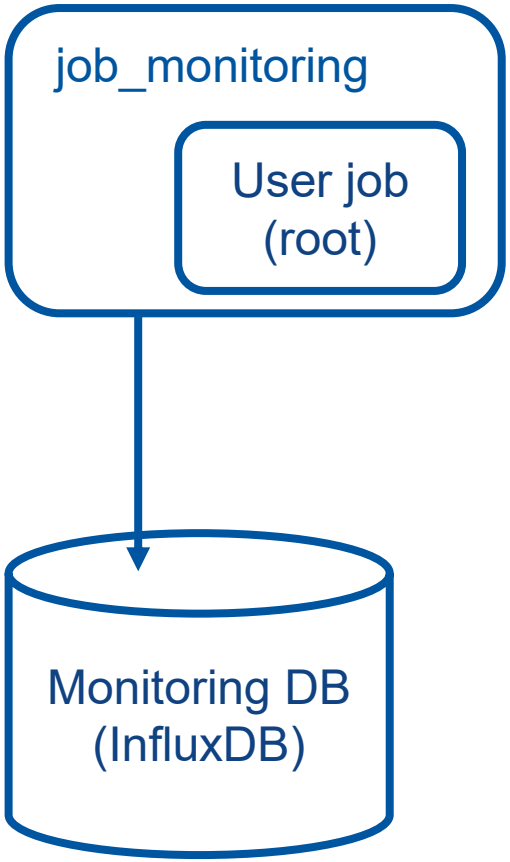
Parameters example

- If we have **20** computing worknodes, **40** cores available on each worknode.
- If **100 MB/s** maximum disk writing speed on each worknode.
- If new **40 GB** RAW file appears every **90** seconds. 105000 events in each RAW file.
- If each event processing time is 0.5 sec – one file processing will last for **14.5** hours.

User job monitoring

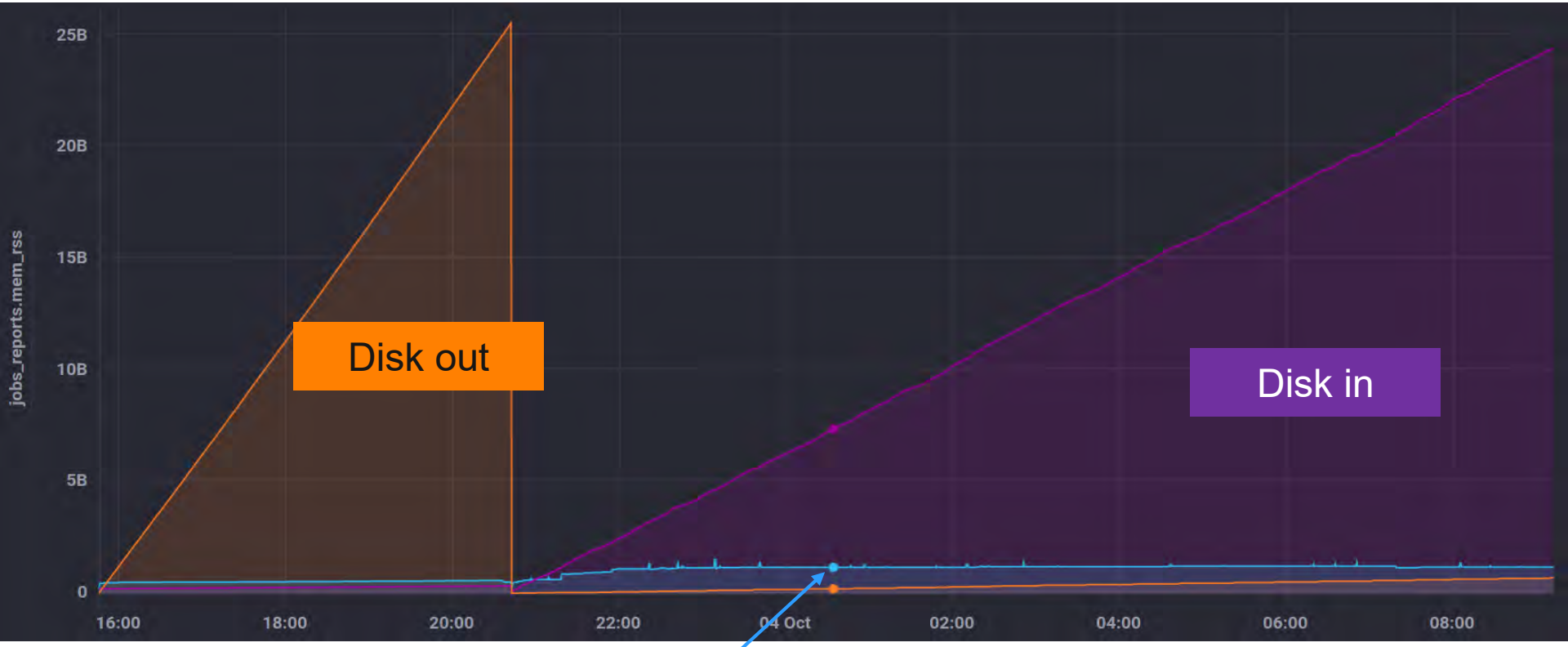
```
$ root macro.c(input)
```


```
$ job_monitoring root macro.c(input)
```



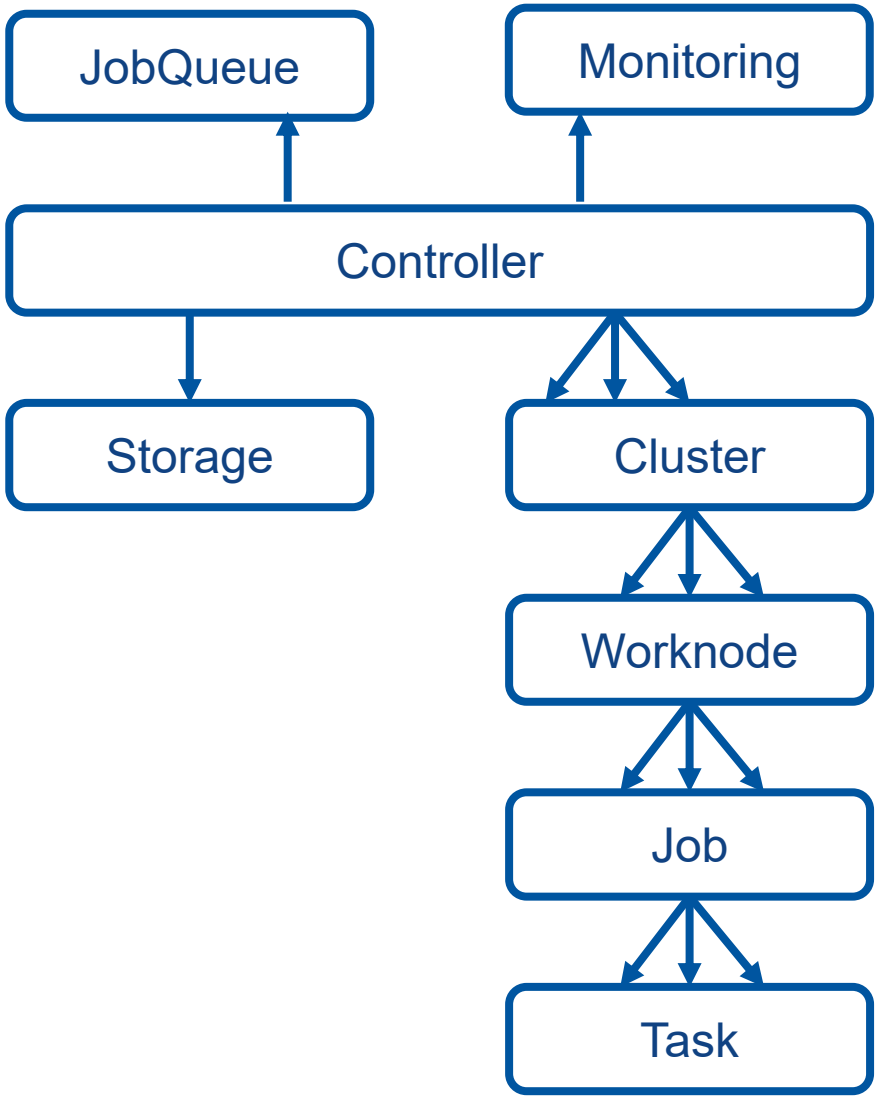
User job monitoring

GenToDst job on Govorun



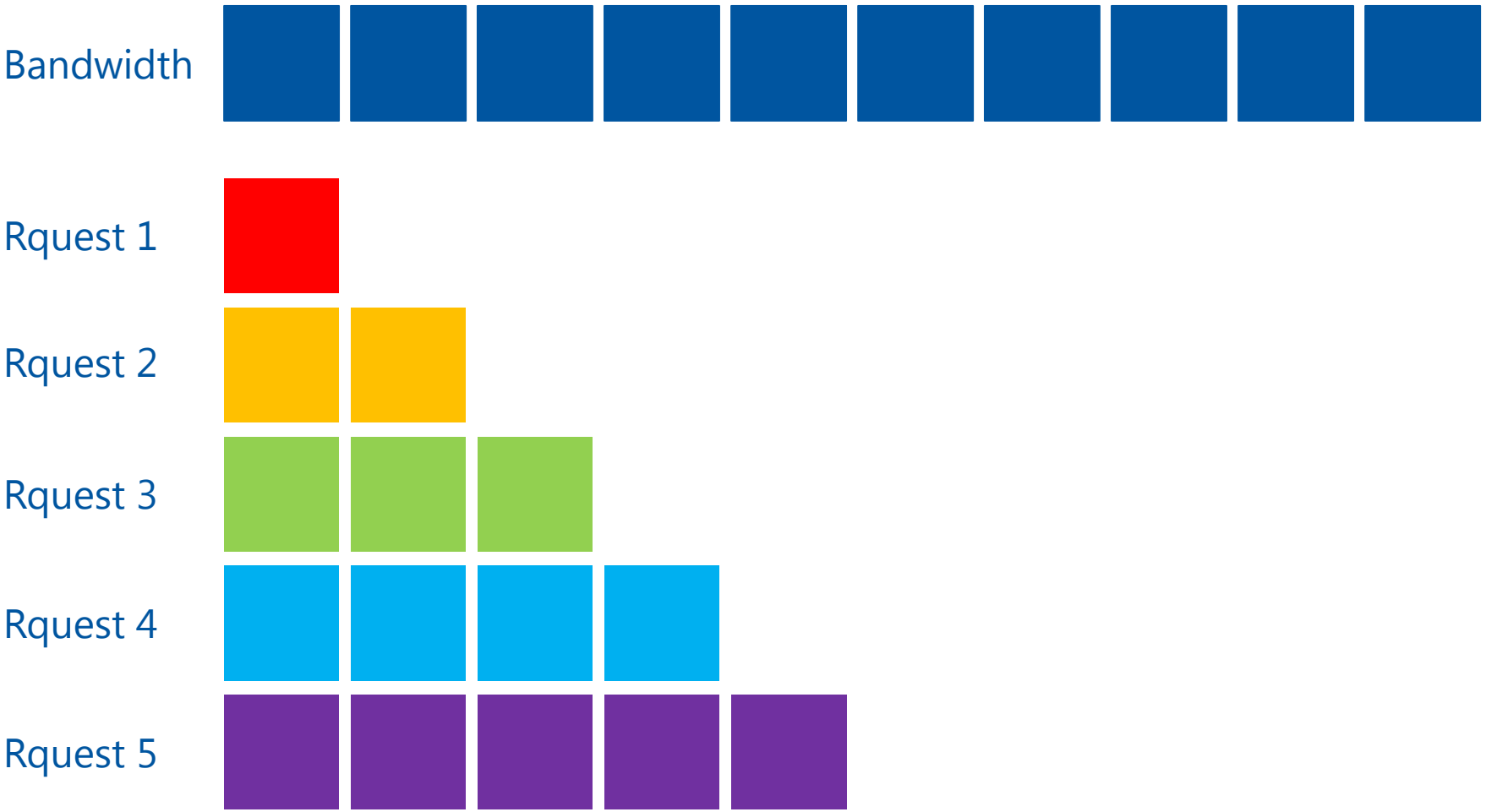
Simulation system

- Written in python to predict CPU, RAM, network and disk load
- Uses data about performance of resources integrated in DIRAC
- It is used to check the behavior of DIRAC jobs in real infrastructure.
- Simulation is done every second, but period may be increased for speeding up simulation.
- InfluxDB is used for results storage and visualization



Most important part

transfer simulation



Simple approach

Bandwidth

Rquest 1

Rquest 2

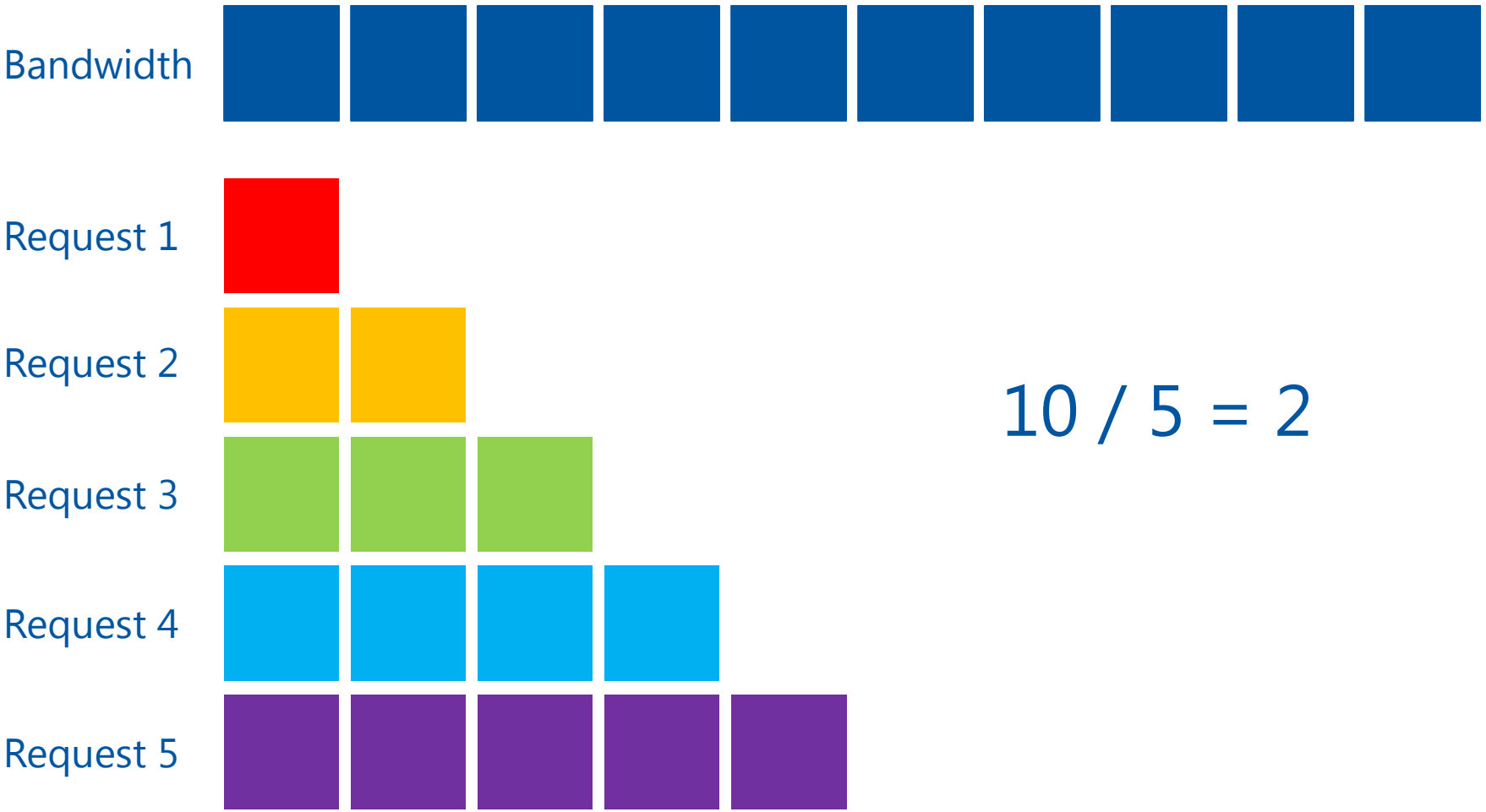
Rquest 3

Rquest 4

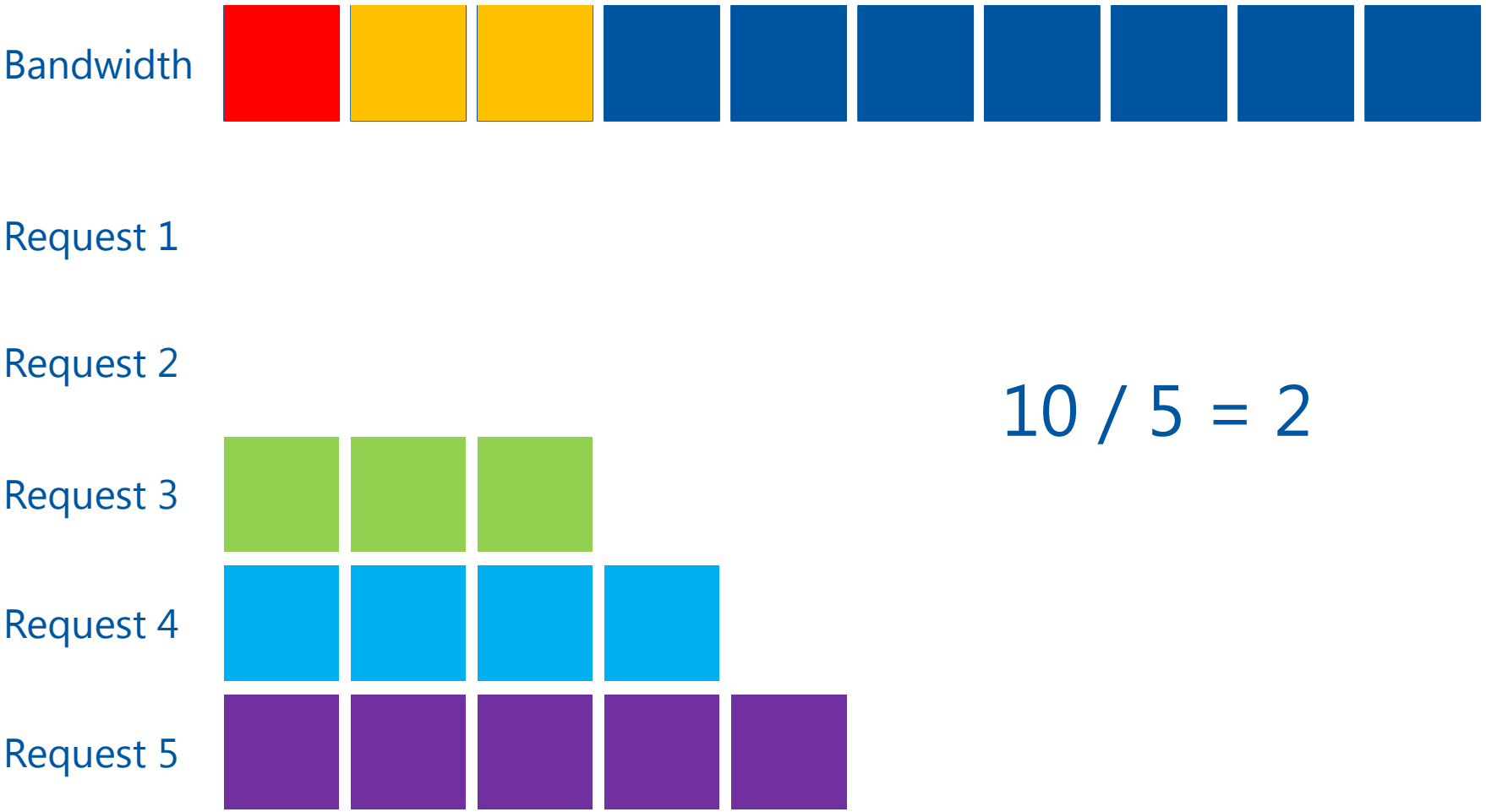
Rquest 5

10 / 5 = 2

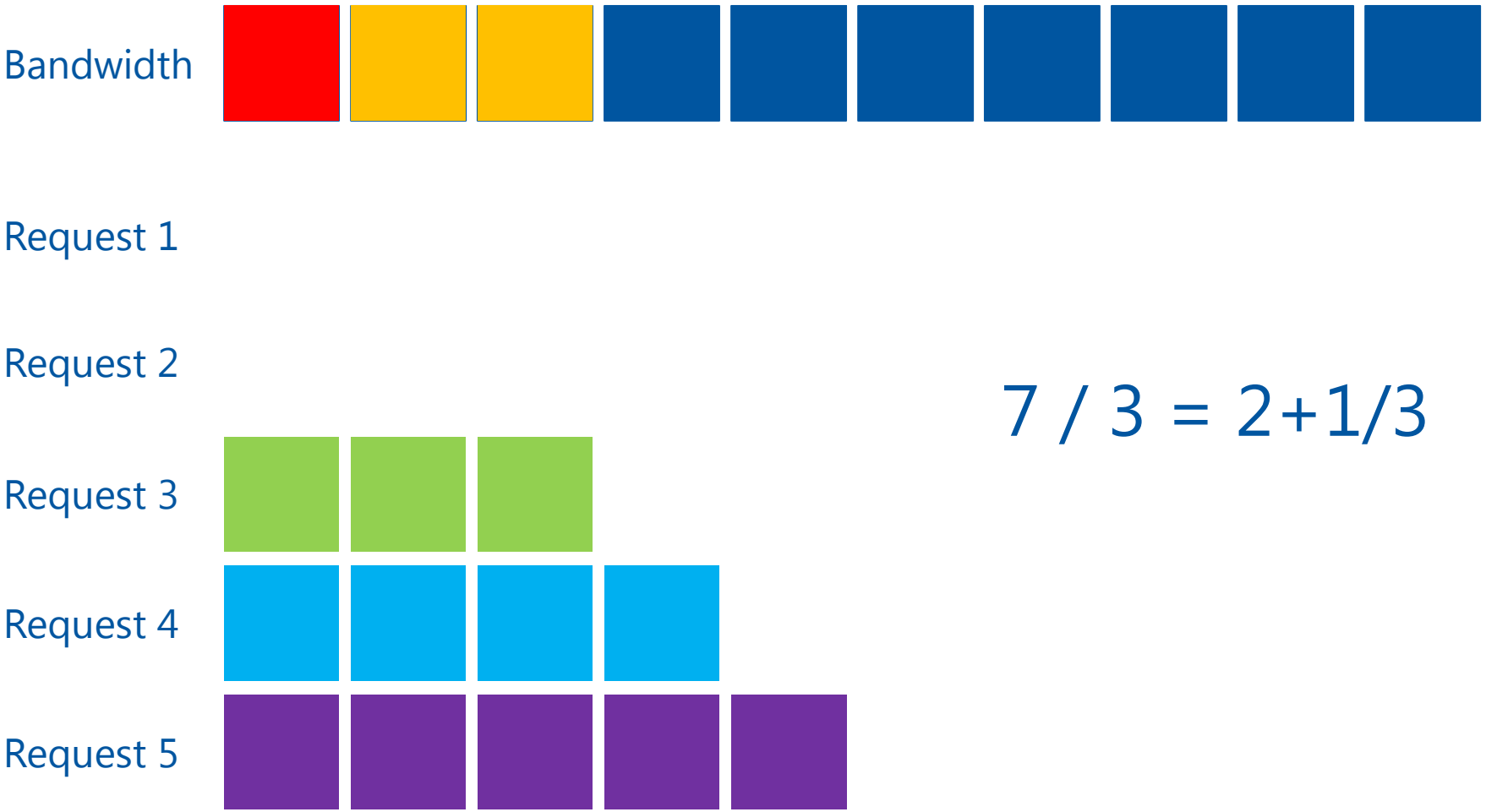
Used approach



Try to apply share



Recalculate share

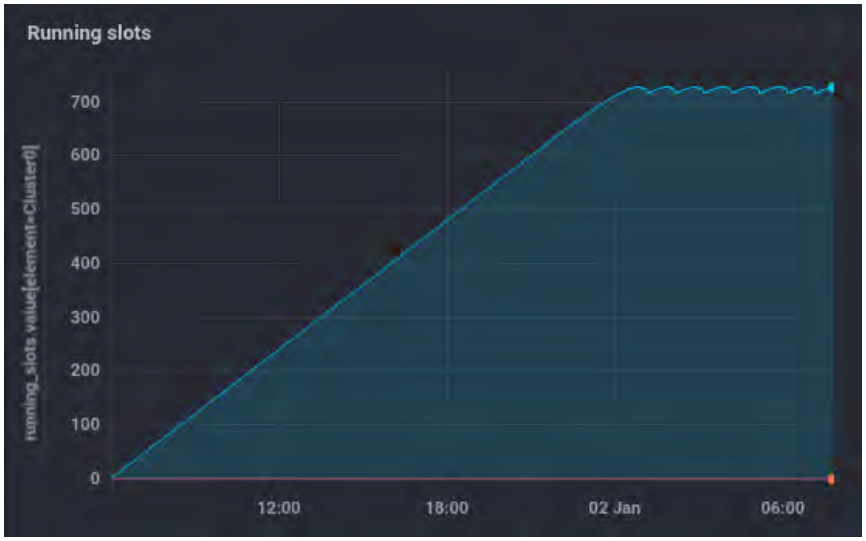


Apply share

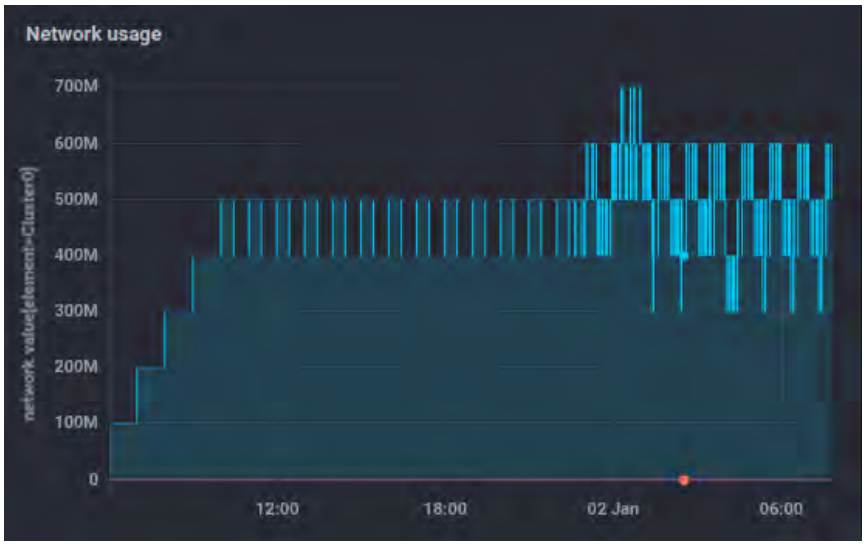

Bandwidth
Request 1
Request 2
Request 3
Request 4
Request 5
7 / 3 = 2+1/3
These are left for the next simulation period

Results -1

Jobs are submited sequentially on each worknode until it is full

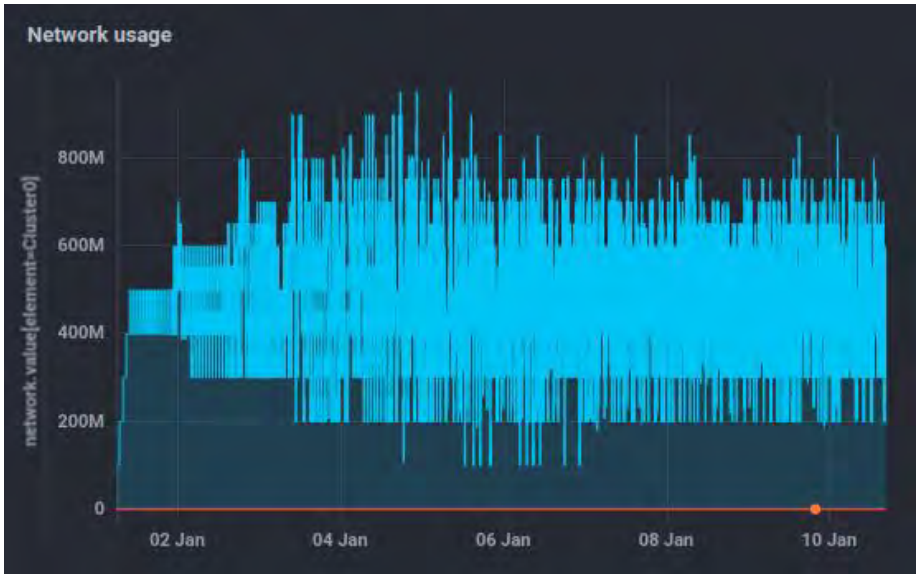


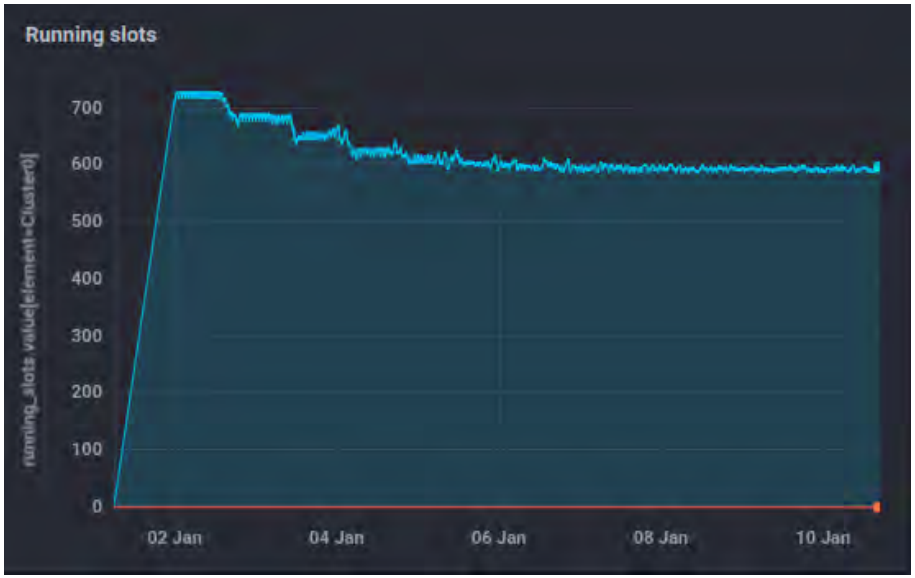
- Stable state of the system after ~19 hours
- Maxmim amount of running jobs ~730 (91% of slots)
- Eventually ~592 slots required
- Initial CPU load of available resources ~ 80%.



- Network usage not more than 700 MB/s
- Average usage between 400 and 500 MB/s

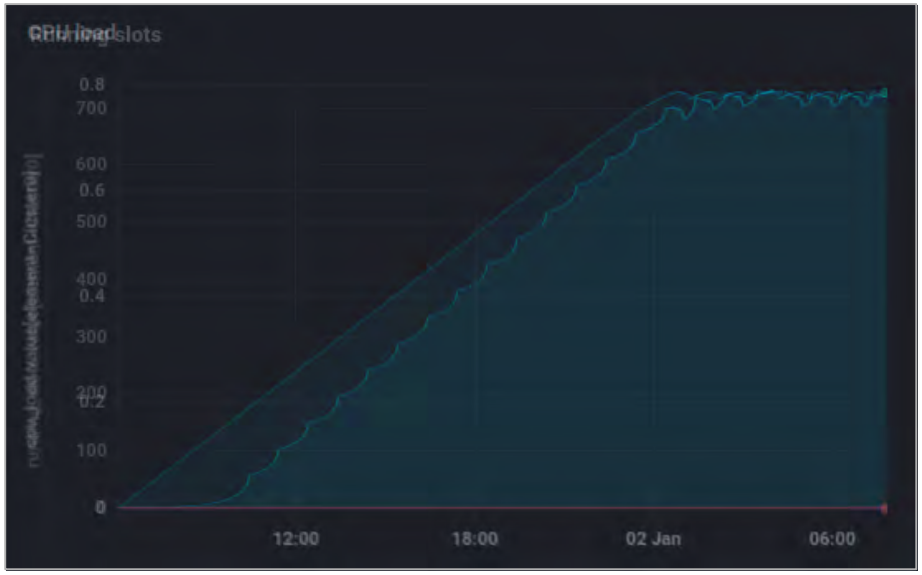
Results - 1


Network usage
network.value[element=Cluster0]
800M
600M
400M
200M
0
02 Jan
04 Jan
06 Jan
08 Jan
10 Jan


Running slots
running_slots.value[element=Cluster0]
700
600
500
400
300
200
100
0
02 Jan
04 Jan
06 Jan
08 Jan
10 Jan


CPU usage
cpu.value[element=Cluster0]
14K
12K
10K
8K
6K
4K
2K
0
02 Jan
04 Jan
06 Jan
08 Jan
10 Jan

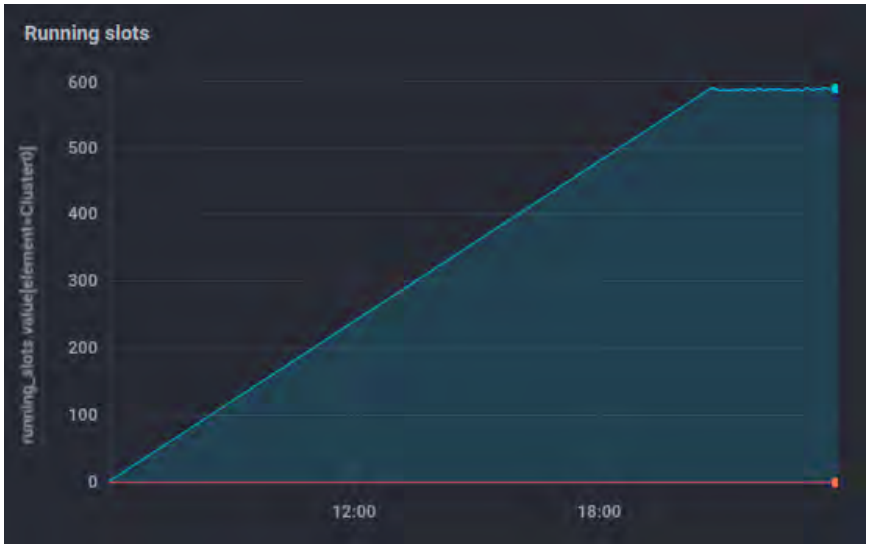
Strange results



- These “waves” are on CPU load graph is definitely an issue.
- If we place Running slots graph on top of CPU load graph we see that in the beginning many slots occupied by jobs which struggle to download data.
- What if we will distribute jobs among worknodes randomly?

Results -2

Jobs are submited on a random worknode

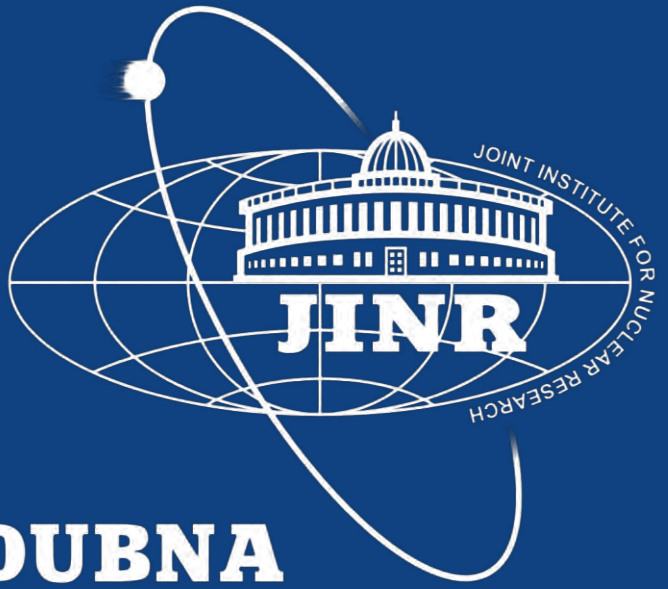


- No disaster happening
- Stable state of the system after ~15 hours
- Maxmim amount of running jobs ~591 (74% of slots)
- Average CPU load of available Govorun resources ~ 73%.

- Network usage not more than 700 MB/s
- Average usage ~450MB/s

Conclusion

- Simulation of job execution can give accurate predictions of a load
- Accuratnes of prediction highly depends on initial parameters
- With simulation it is possible to estimate network load which is the biggest limiting factor in real job execution
- Special use-case simulation was performed in order to validate simulation results. **Thank to Daria Pryakhina and the team from *Simulation results of BM@N computing infrastructure* talk**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