Towards a container-based architecture for CMS data acquisition

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Outlook

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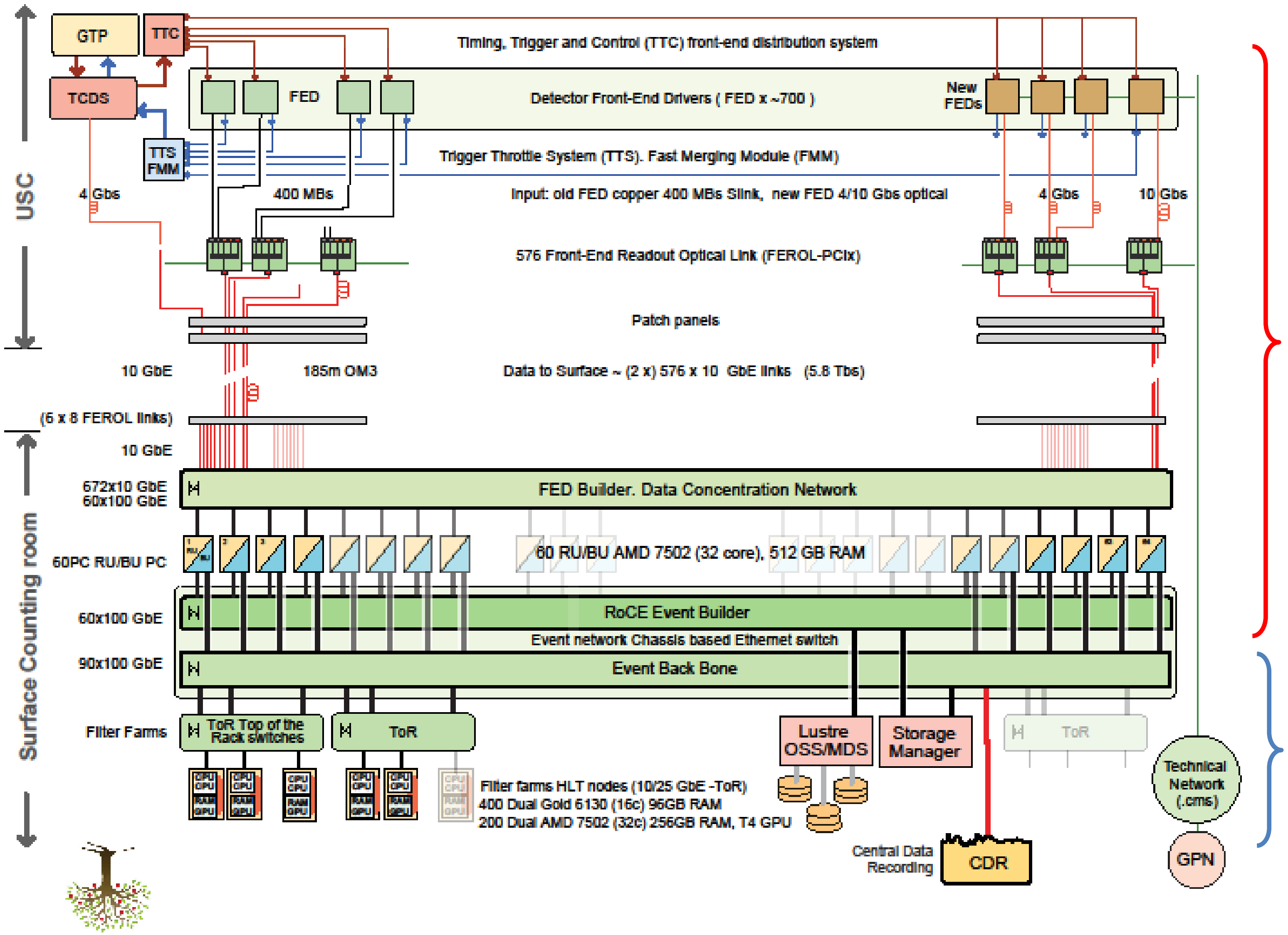
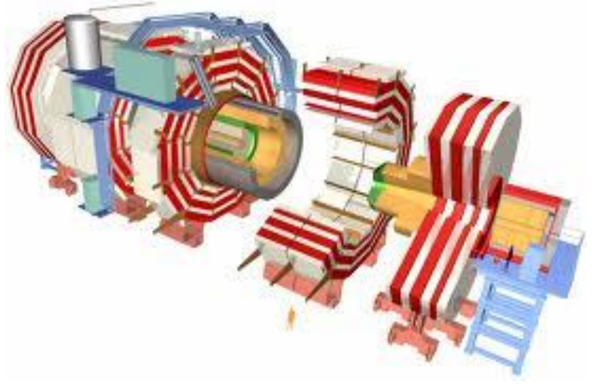
- Motivation
- Pilot project
- Conclusion

Introduction

CMS Data Acquisition (DAQ) for LHC run 3





DAQ as a service-oriented architecture

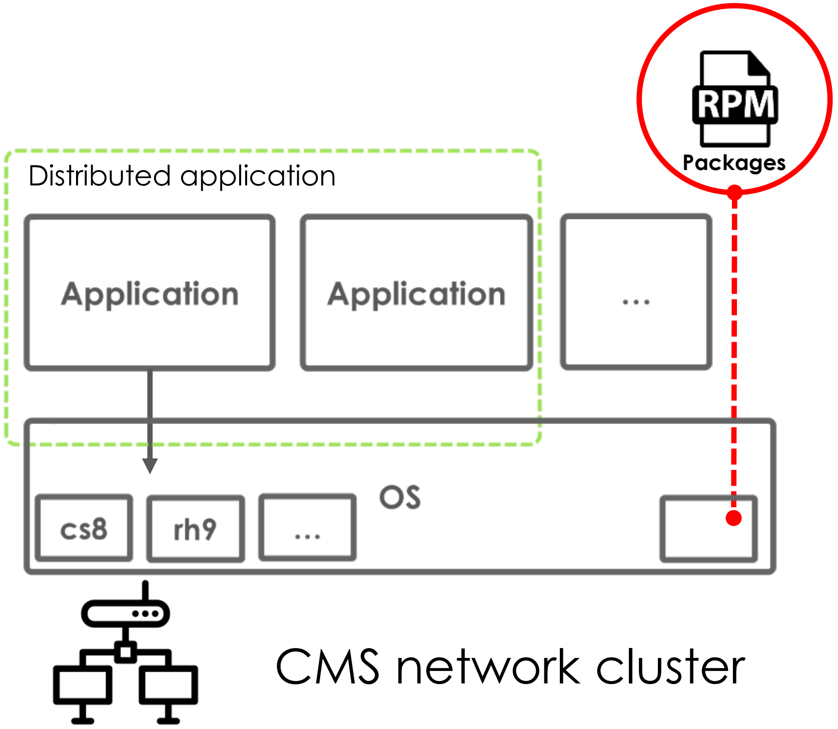
- DAQ is implemented as a service-oriented architecture where DAQ applications, as well as general applications such as monitoring and error reporting, are run as self-contained services
- The task of deployment and operation of services is achieved by using several heterogeneous facilities, custom configuration data and scripts in several languages
- Deployment of all software is carried out by installation of rpms through Puppet management system on physical and virtual machines in computer network
- Two main approaches are used to operate and control the life cycle of the different services: short-lived services, such as event building and read-out, are managed using a custom-built infrastructure, while auxiliary, long-running services are managed using systemd

Motivation

Motivation

- The current system works well, nevertheless we identified points of improvement for the future system
- User experience and lessons learned provided a groundwork for reassessment of the software
- The are opportunities coming from new technologies
- Coping with a changing environment

Points to improve (1)



- Infrastructure lock-in caused by dependency on a given operating system and libraries. Inability to use different alternatives without substantial switching costs.
- Time consuming transition from development to deployment.
- Significantly different development, validation and production environments.

Points to improve (2)

- Non-optimal usage of hardware resources due to application binding to physical or virtual machines
- Cost-intensive building of development and validation environments
- Update and rollback of software is non-trivial
- The need for system administration effort during deployment and operation
- Lack of portability regarding physical host, network or system reconfiguration
- Need for custom (private) scripts for software deployment and operation of distributed applications in development and test environments

System homogenization

- Two approaches to operate and control the life cycle of services
  - Custom-built infrastructure for short-lived application services (e.g., event building and read-out)
  - Systemd for long-running application services (e.g., monitoring)
- Restructuring the existing system into a homogeneous, scalable cloud architecture adopting a uniform paradigm where all applications are orchestrated in an environment with standardized facilities

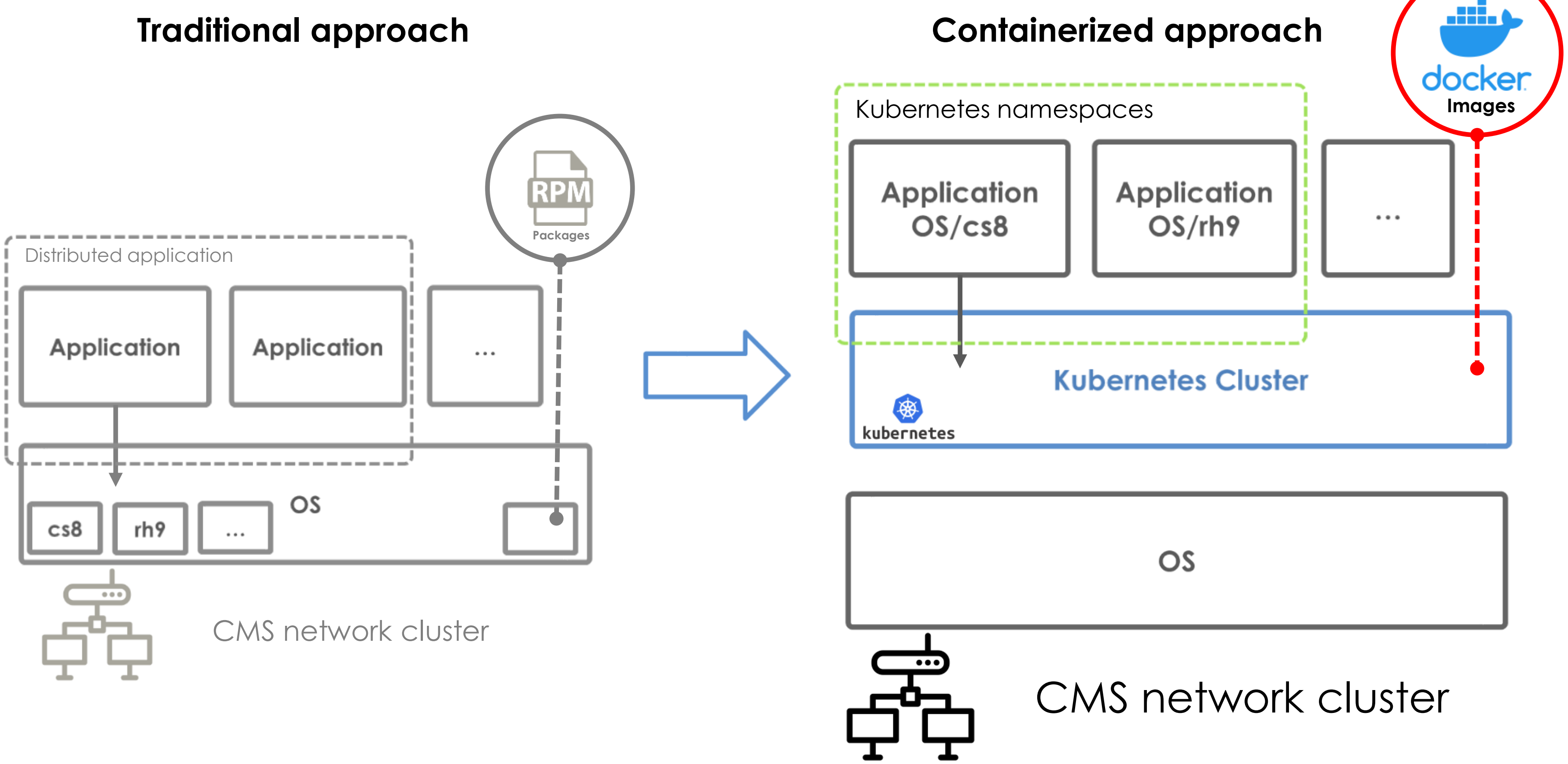
Container-based architecture

- In this new paradigm DAQ applications are organized as groups of containers and the required software is packaged into container images

- Automation of all aspects of coordinating and managing containers is provided by the Kubernetes environment, where a set of physical and virtual machines is unified in a cluster of compute resources

- More reliable validation of software in test or production environments
  - Consistent installation on different targets is guaranteed by image construction at build time
  - Tests in production environment do not disrupt installation, roll back of installed software is not needed

Containerization approach



- Containerization transforms the network from being machine-oriented to being application-oriented
- Container image encapsulates all (or almost all) of an application's dependencies

Pilot project

Goals

- Achieve extensive use of the cloud approach by homogenizing DAQ system elements into Kubernetes patterns.
- Adopt a full software life-cycle for the new environment, focusing on the development, delivery, deployment and operation.
- Resolve issues concerning building and maintenance of Kubernetes cluster and hardware resources. Determine implications on current system administration environment.

Output

- Final output would be to have a working DAQ column from detector front-end to High Level Trigger including run control and monitoring

Scope of the project

- The new approach applies to all dimensions of expertise within CMS DAQ system
  - Operation
  - Development
  - Release
  - Deployment
  - System administration
  - Networking
  - Security
  - Integration

Study modules

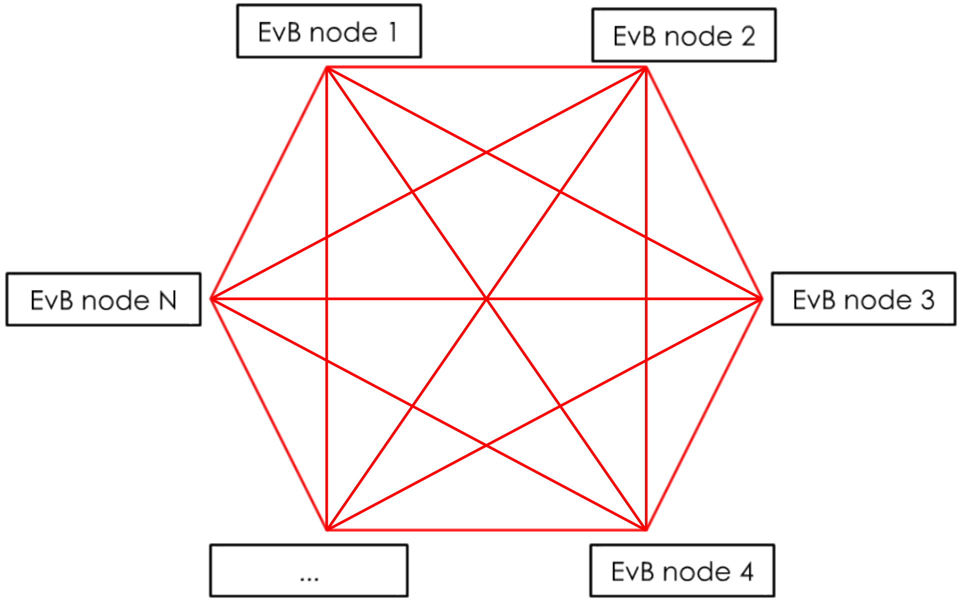
- Performance and scalability
- Hardware access and binding (RDMA, FEROL, PCI, VME, etc.)
- System fine-tuning (driver interrupts, NUMA settings, etc.)
- User access (GUI, CLI, Dashboards, API, etc.)
- Networking (configuration, fine-tuning TCP/IP, RoCE, etc.)
- Control and monitoring
- Configuration
- Additional technologies and their integration (Elasticsearch, Oracle, PVSS, etc.)
- Scalable Event Builder prototype and startup measurements

What was achieved already?

- User access possibilities through GUI, CLI, Dashboards and Kubernetes API were investigated
- RDMA based device access (RoCE) investigated and prototyped
- Various networking possibilities were investigated and prototyped (flannel, Calico, ipvlan)
- Software configuration techniques inside a pod were tested: based on custom scripting and/or Helm scripting
- Elasticsearch and Opensearch were installed and tested inside Kubernetes cluster for monitoring purposes
- Several Event Building prototypes working inside Kubernetes cluster were made (see also presentation “Event Building studies for CMS Phase-2 at CERN” by Andrea Petrucci and Rafał Krawczyk)
- Startup/termination time measurements were performed

Startup/termination measurements

- Event builder is designed as a number of processing nodes communicating to each other to aggregate event fragments
- Measurements of startup time up to the moment when the full pod interconnection is achieved and event builder is ready to take data
- Measurements of termination time for all pods after ready state is achieved

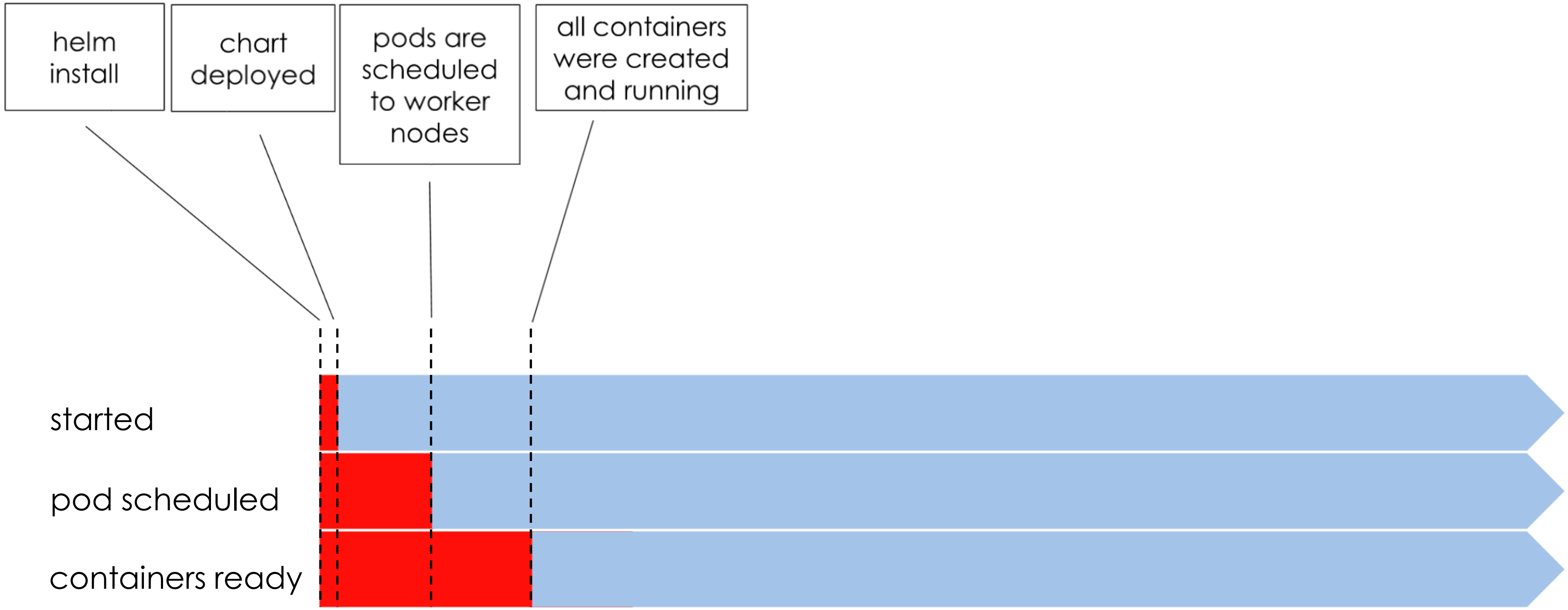


Test cases

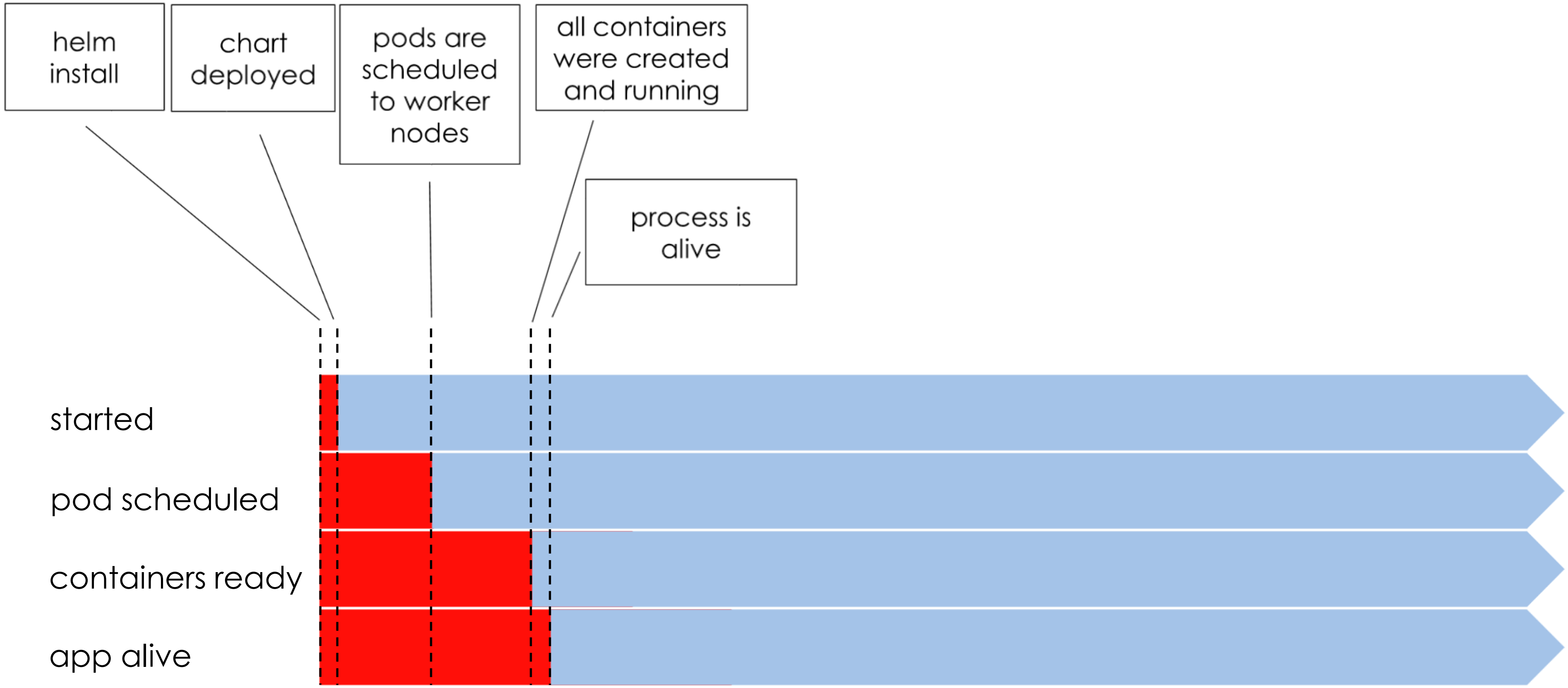
Test cases

helm install
chart deployed
pods are scheduled to worker nodes
started
pod scheduled

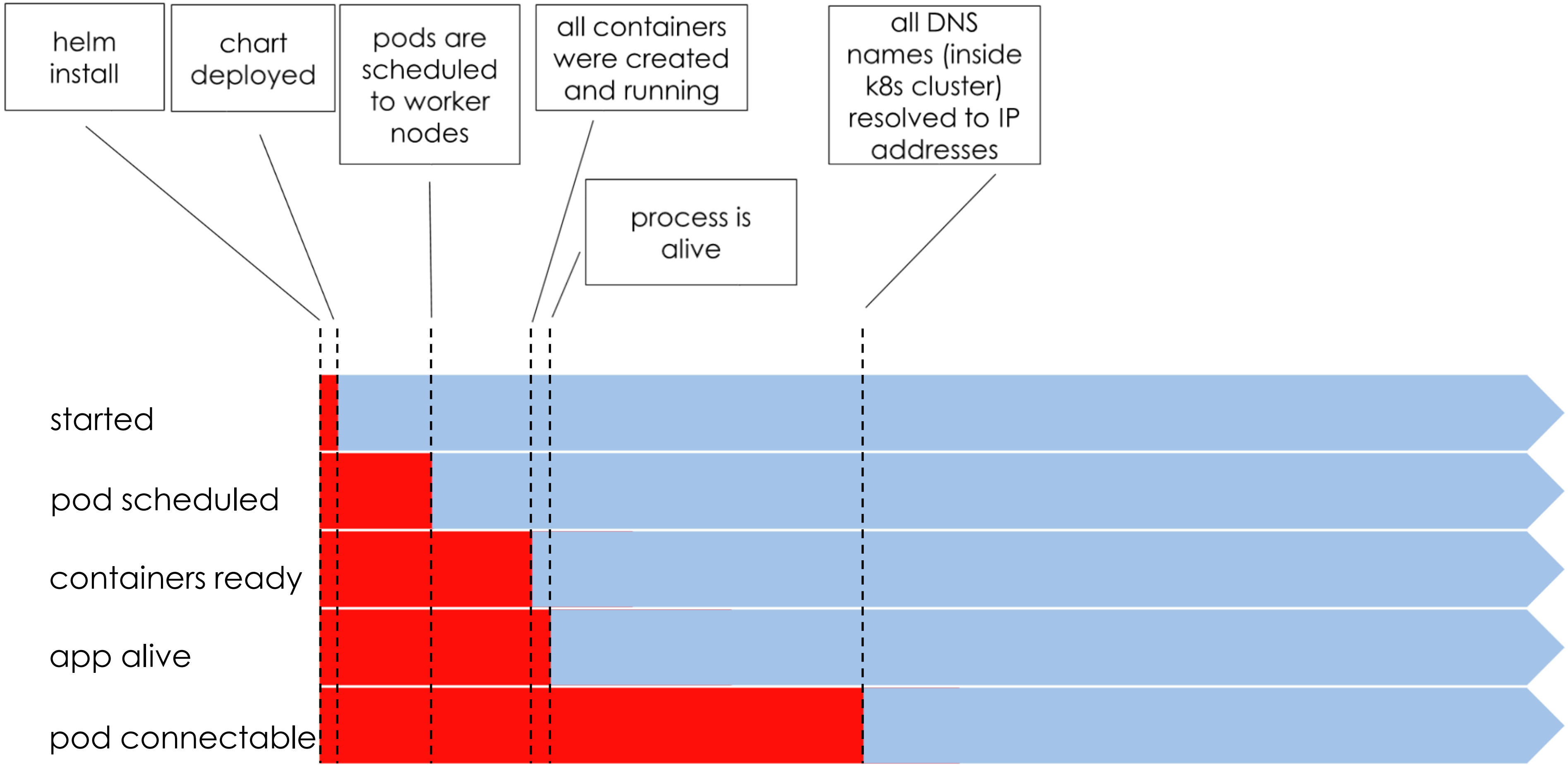
Test cases


helm install
chart deployed
pods are scheduled to worker nodes
all containers were created and running
started
pod scheduled
containers ready

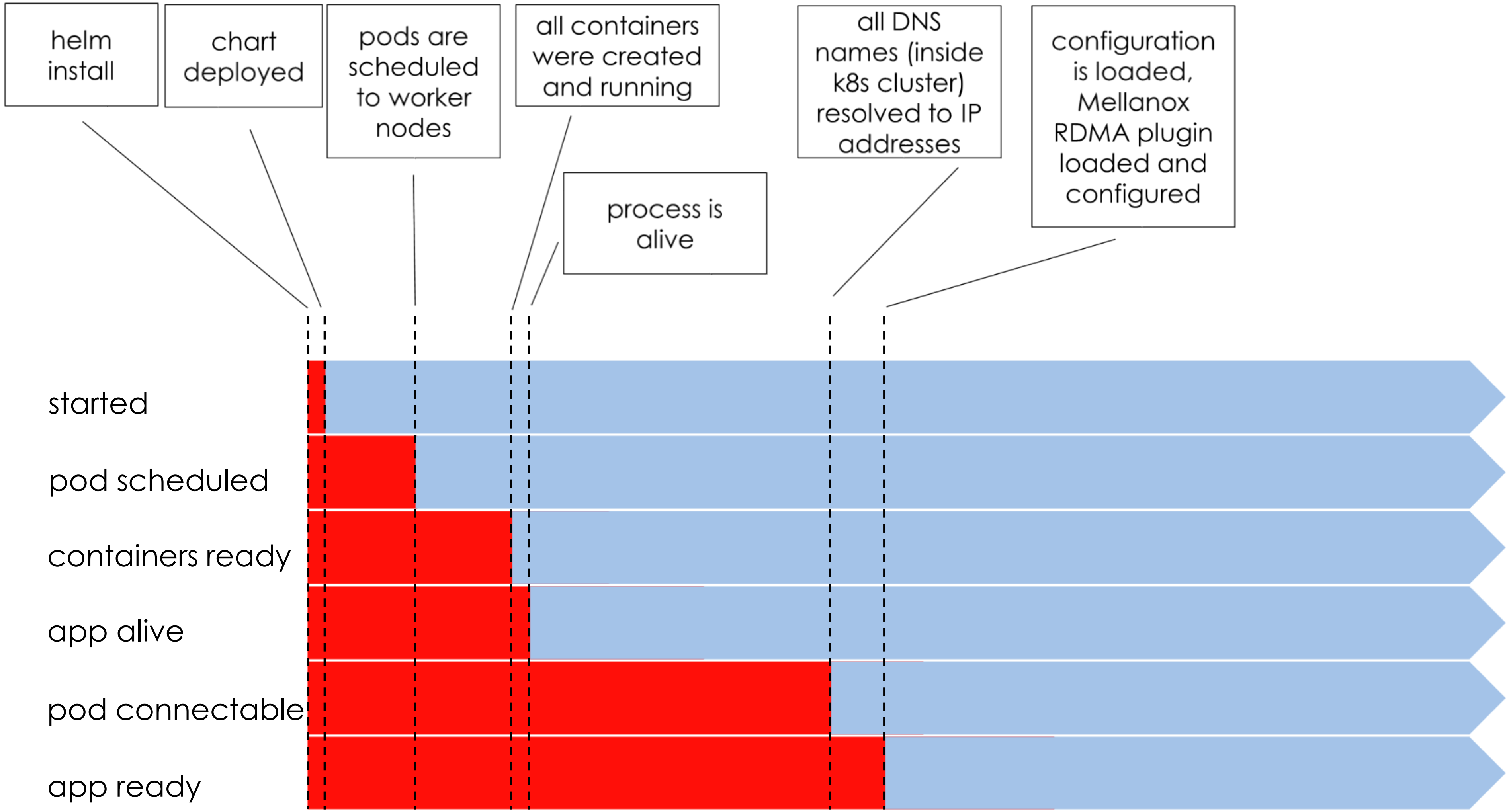
Test cases


helm install
chart deployed
pods are scheduled to worker nodes
all containers were created and running
process is alive
started
pod scheduled
containers ready
app alive

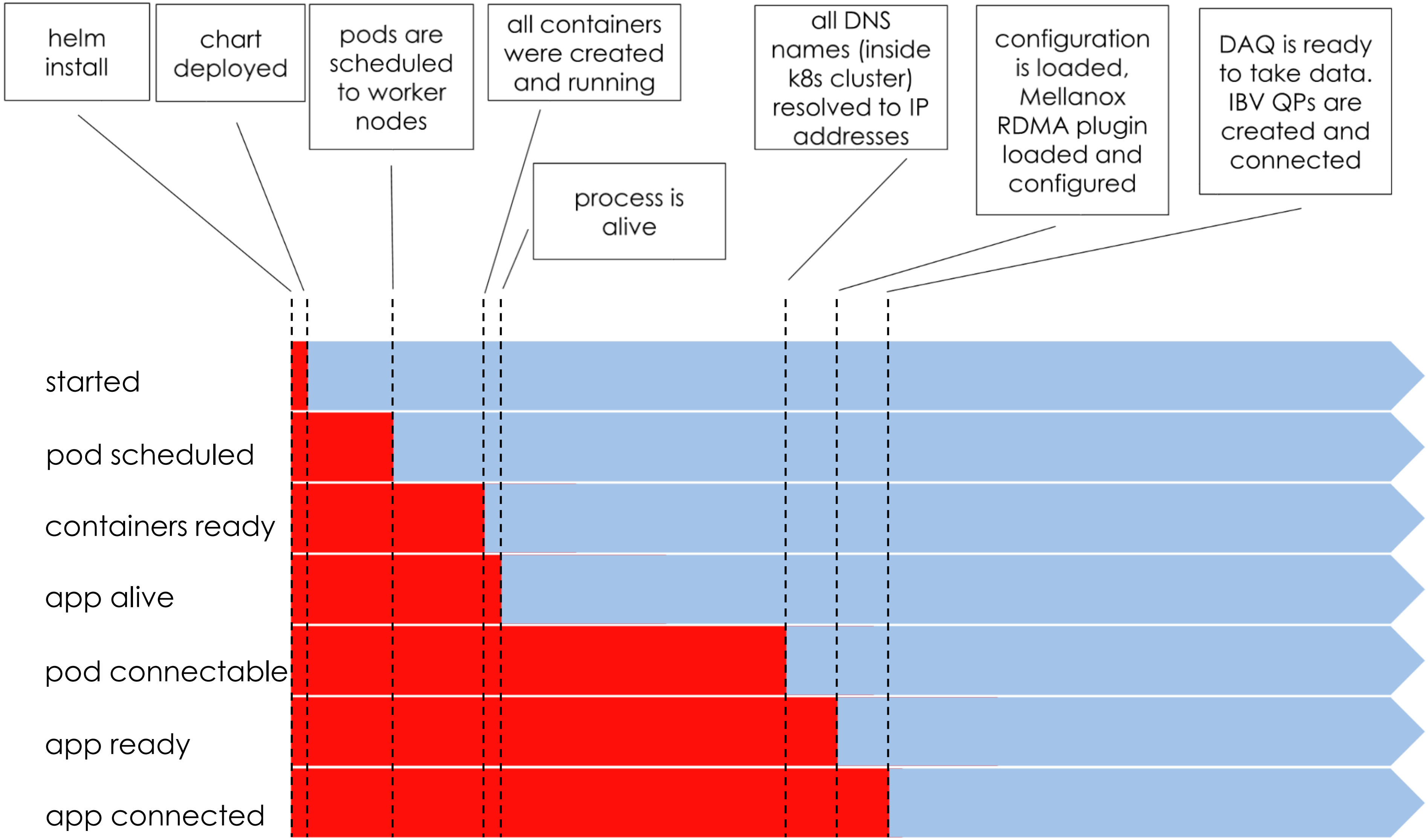
Test cases


helm install
chart deployed
pods are scheduled to worker nodes
all containers were created and running
process is alive
all DNS names (inside k8s cluster) resolved to IP addresses
started
pod scheduled
containers ready
app alive
pod connectable

Test cases

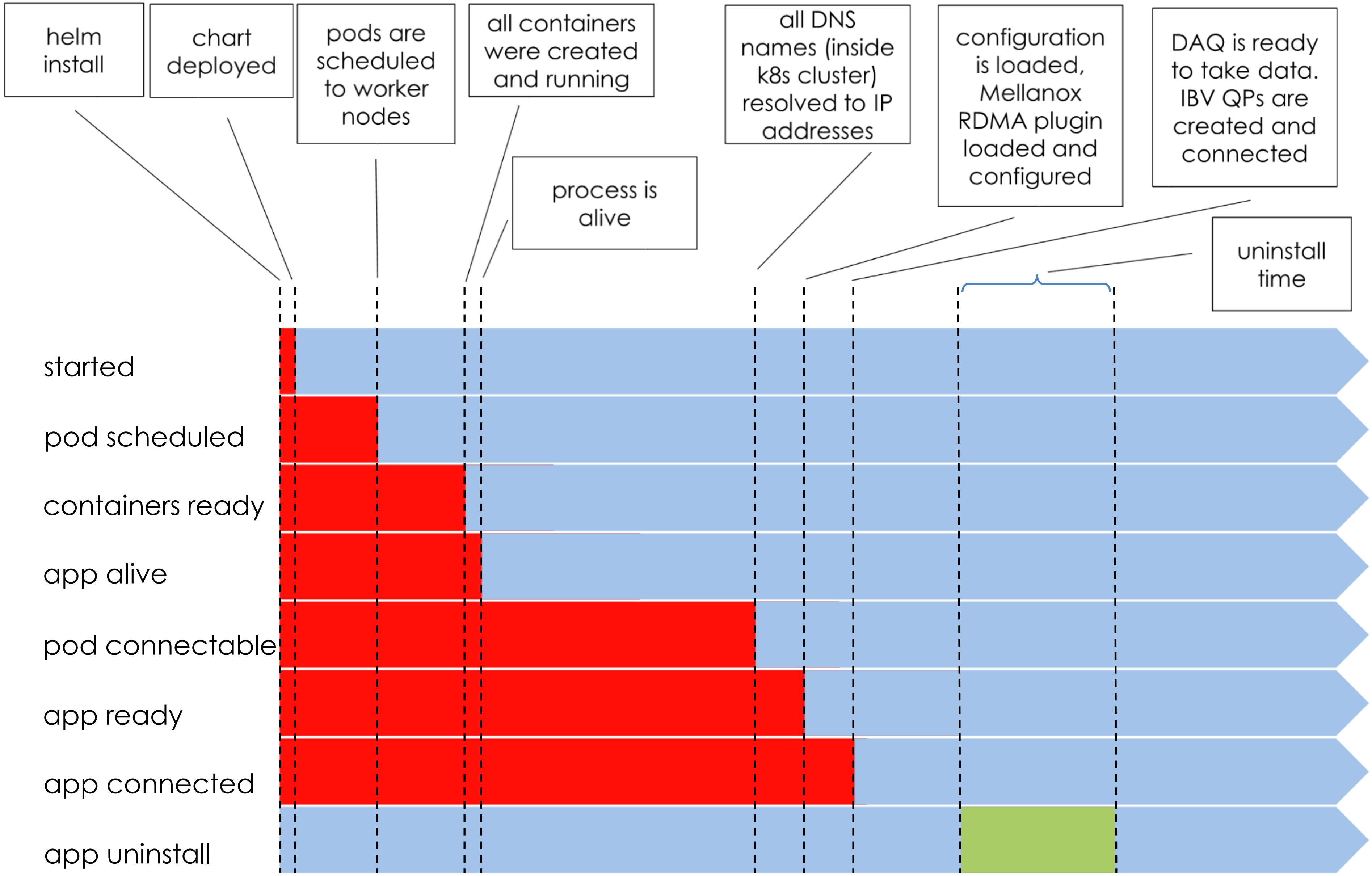

helm install
chart deployed
pods are scheduled to worker nodes
all containers were created and running
process is alive
all DNS names (inside k8s cluster) resolved to IP addresses
configuration is loaded, Mellanox RDMA plugin loaded and configured
started
pod scheduled
containers ready
app alive
pod connectable
app ready

Test cases

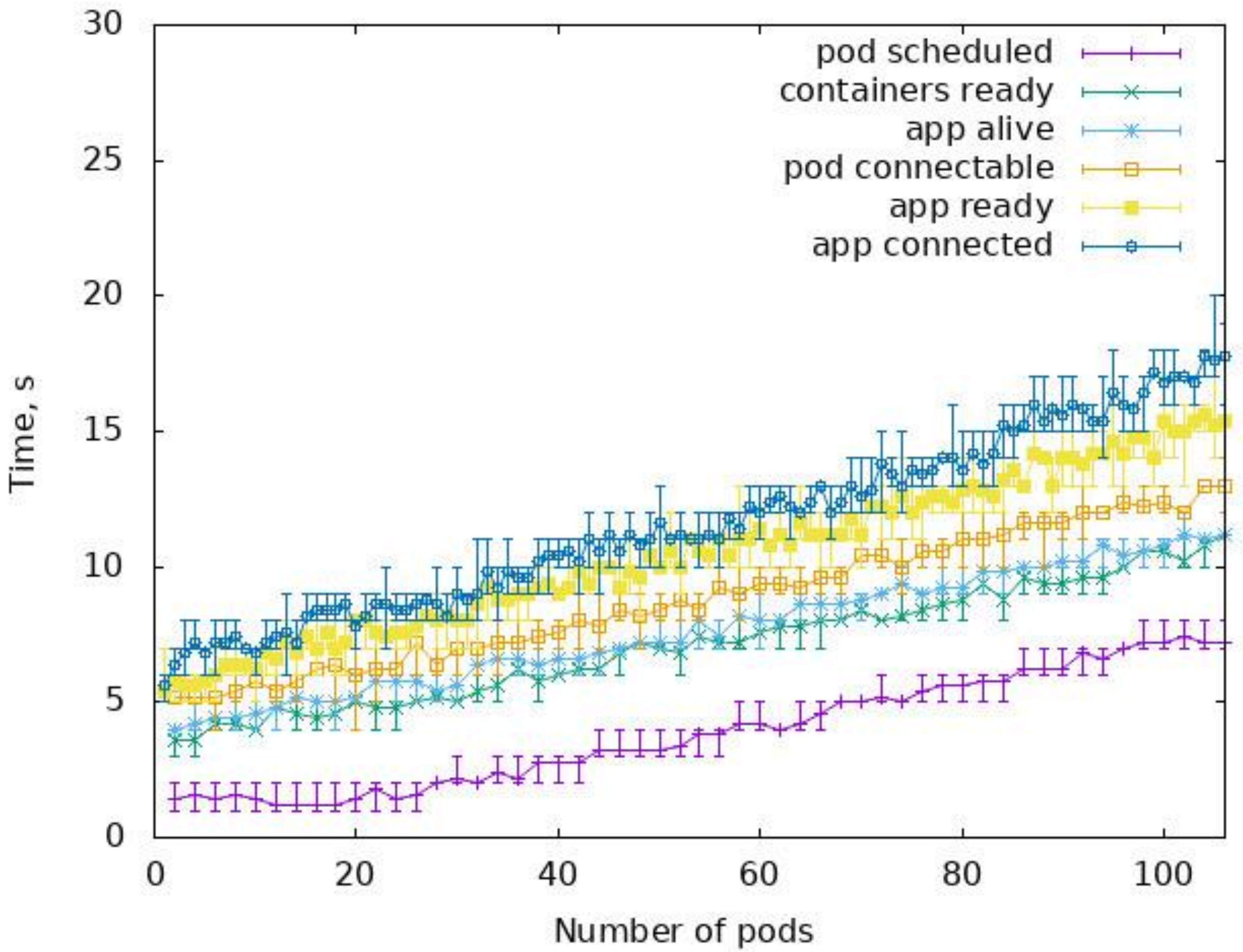


helm install
chart deployed
pods are scheduled to worker nodes
all containers were created and running
process is alive
all DNS names (inside k8s cluster) resolved to IP addresses
configuration is loaded, Mellanox RDMA plugin loaded and configured
DAQ is ready to take data. IBV QPs are created and connected
started
pod scheduled
containers ready
app alive
pod connectable
app ready
app connected

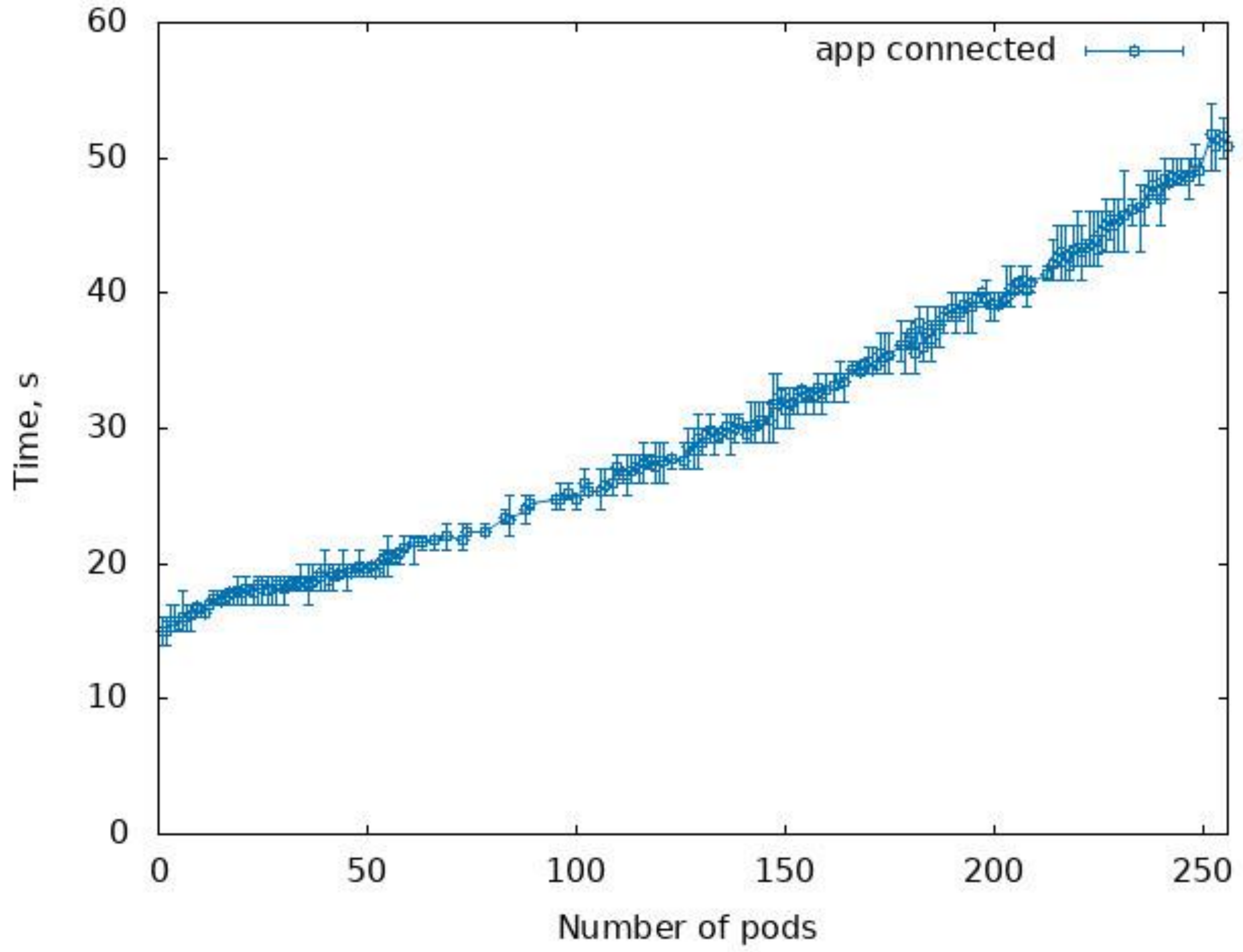
Test cases


helm install
chart deployed
pods are scheduled to worker nodes
all containers were created and running
process is alive
all DNS names (inside k8s cluster) resolved to IP addresses
configuration is loaded, Mellanox RDMA plugin loaded and configured
DAQ is ready to take data. IBV QPs are created and connected
uninstall time
started
pod scheduled
containers ready
app alive
pod connectable
app ready
app connected
app uninstall

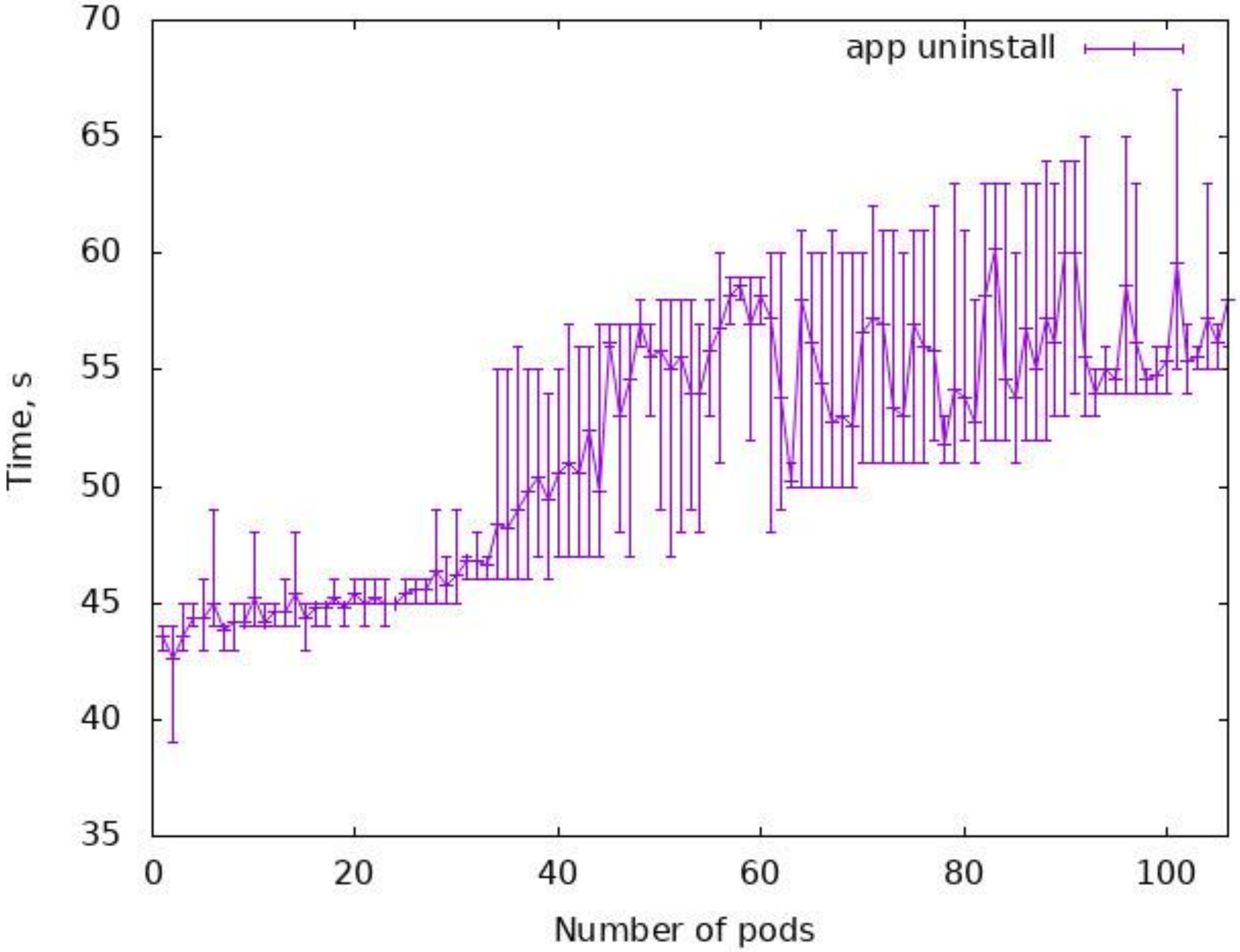
Startup time (one pod per node)



Startup time (several pods per node)



Termination time



Conclusion

Conclusion

- Encouraging results were achieved so far, containerization was shown to be an appealing technology for DAQ applications as a replacement for a bare metal infrastructure
- Containerization and orchestration solve most of constraints experienced by running with a traditional infrastructure
- The approach fits well with distributed inter-communicating applications such as event builder
- No limitations of the approach were discovered during investigation of predefined objectives

Future work

- Continue working on unresolved study modules
- Finalize a working DAQ column from detector front-end to High Level Trigger

Questions?