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HPC Scheduling with Kubernetes

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Agenda

- Project goals
  - Introduction to Kubernetes and plug-in schedulers
  - Problem description
  - Problem demonstration
- Accomplishments
  - Job cancellation management: Pod Informer solution
  - Pod Informer demonstration
  - Pod Informer Performance analysis
  - First steps for co-scheduling: Json Graph Format (JGF) Operator solution
- Conclusion and future improvements

Kubernetes and KubeFlux

- Kubernetes is a portable, extensible, open-source platform for managing containerized workloads and services.
- While Kubernetes excels at orchestrating containers, high-performance computing (HPC) applications can be tricky to deploy on Kubernetes.

- Kube-Flux is an HPC scheduler that employs the Fluxion library to take scheduling decisions on Kubernetes.

State Inconsistency between KubeFlux and Kubernetes

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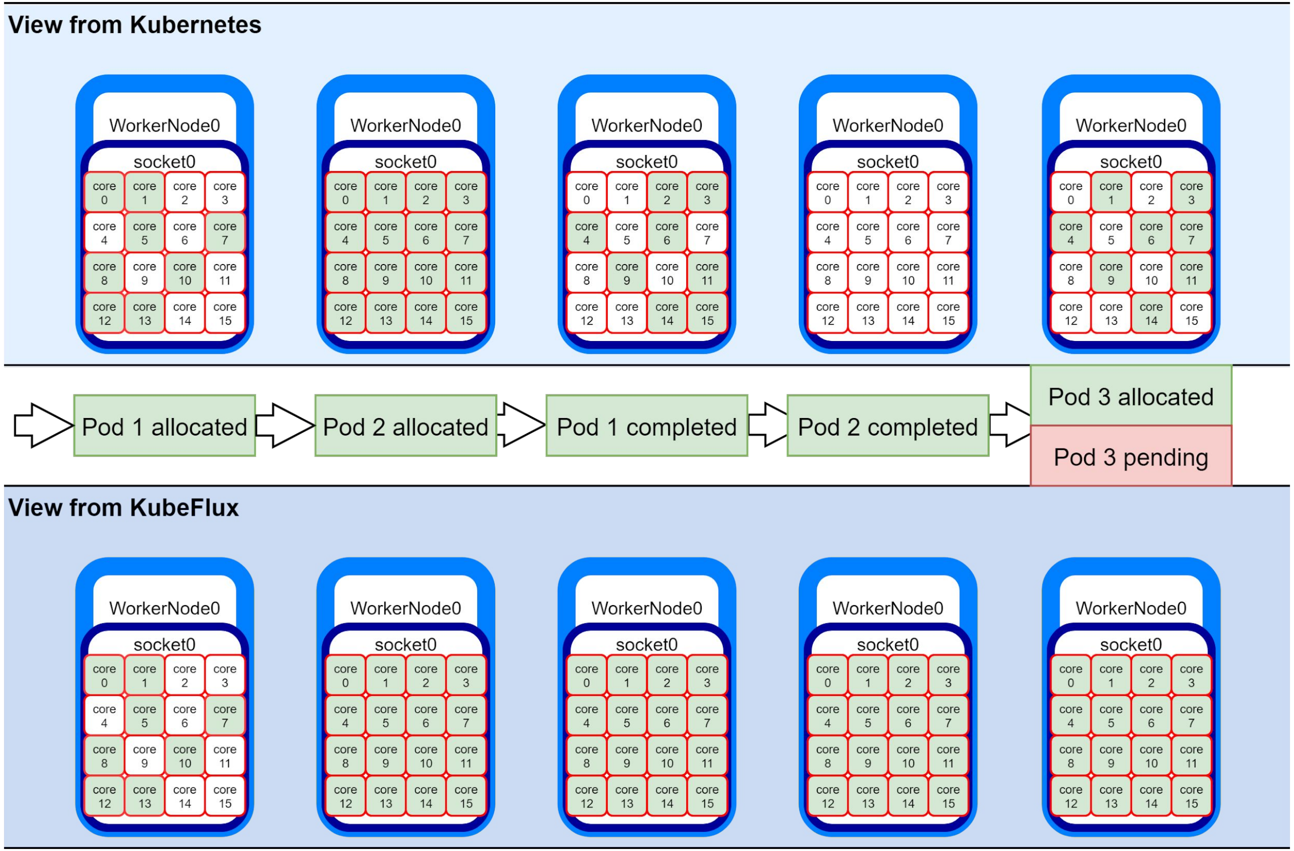
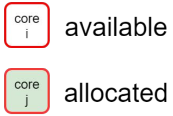


- Cluster has 1 worker node with 1 cpu socket. It has 16 cores
- Pod 1, 2 ,3 requires 8 cores



Problem demonstration

- Environment: A cluster running on local machine
  - 2 compute nodes
    - 1 Master node: Kubernetes control plane
    - 1 worker node
      - 16 virtual cpu cores
- Tools:
  - Kind
  - Docker
- Task:
  - Deploy 4 pods scheduled by KubeFlux, each pod requires 8 cpu cores
- Goal
  - Demonstrate the original KubeFlux can not reuse resources

Solution - Informer

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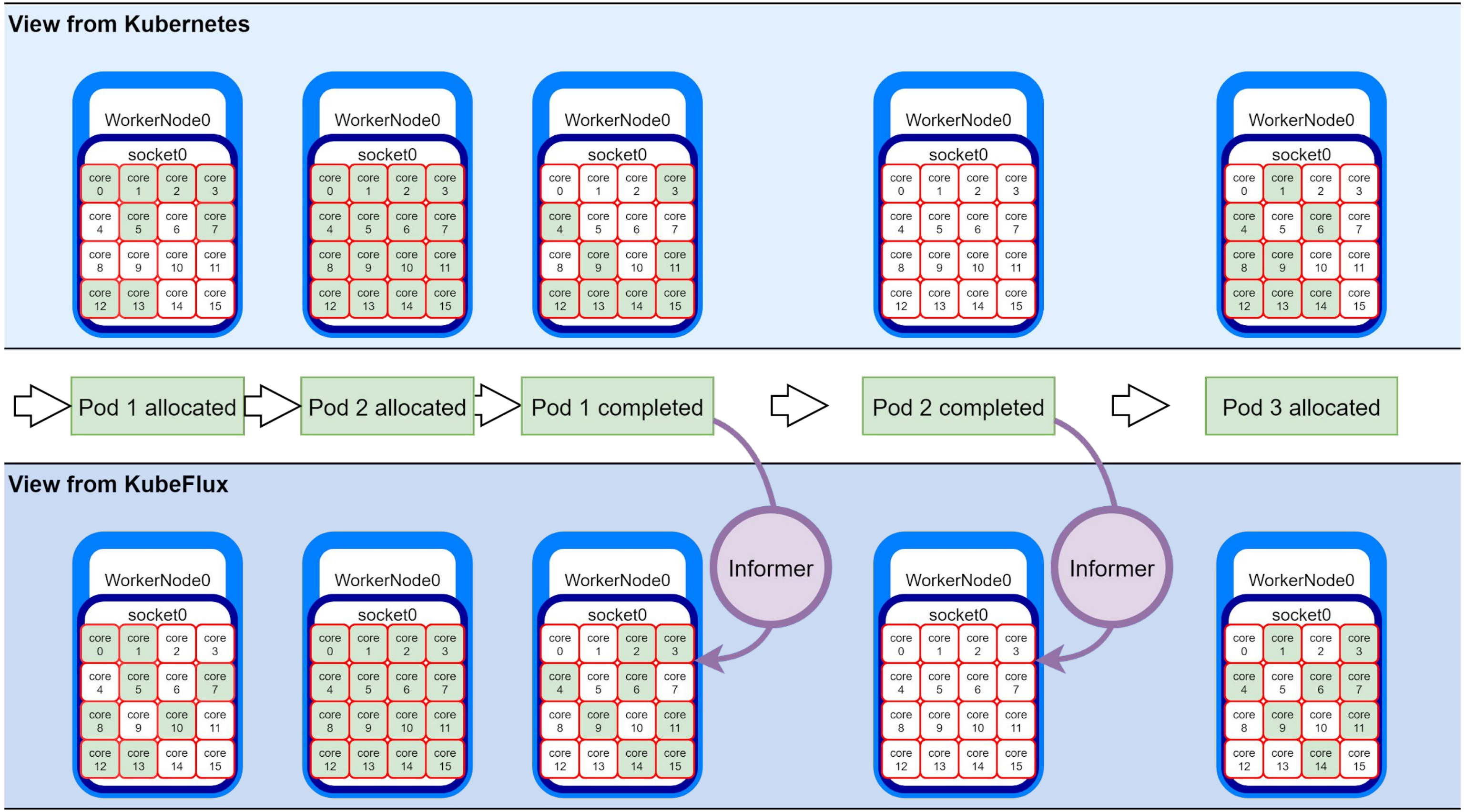
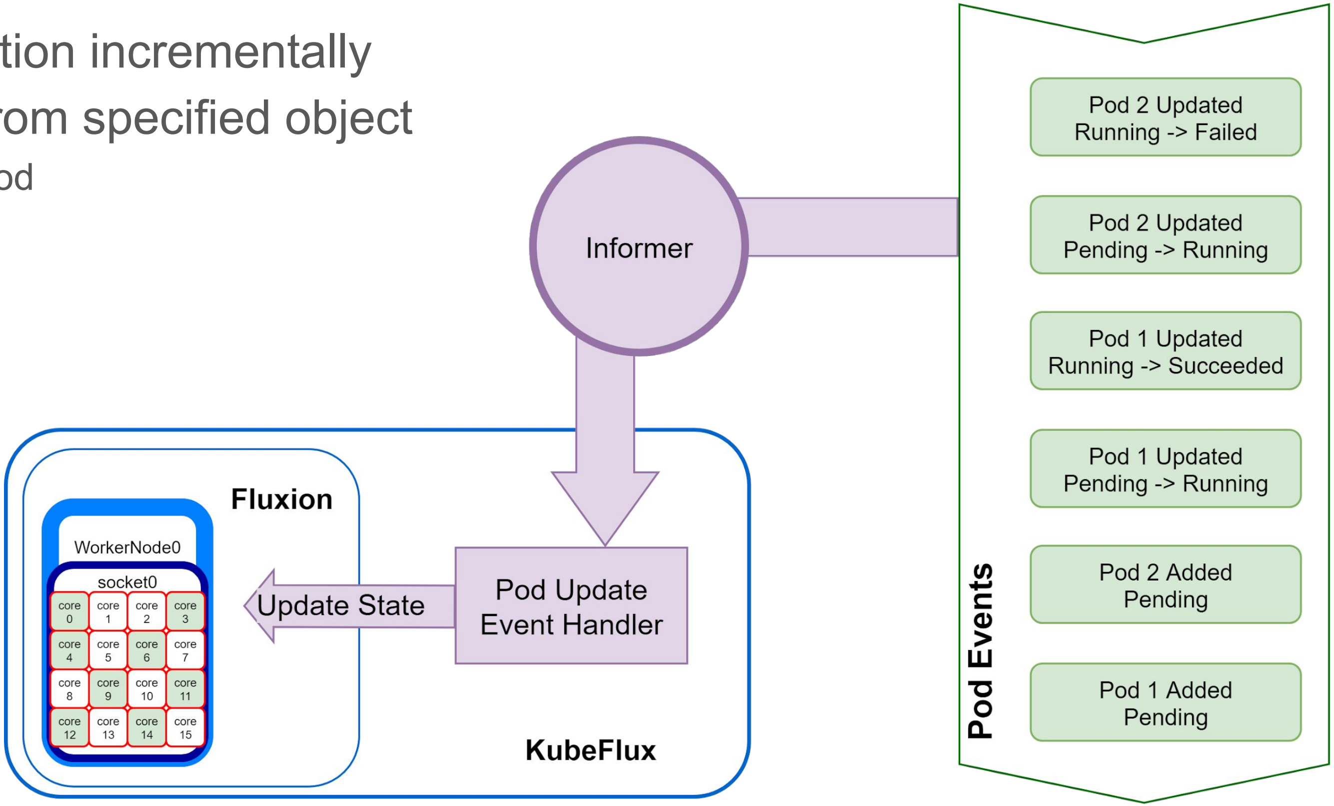


Cluster has 1 worker node with 1 cpu socket. It has 16 cores

Pod 1, 2 ,3 requires 8 cores

Closer look: Kubernetes Informer

- Update information incrementally
- Watch events from specified object
    - In our case: pod

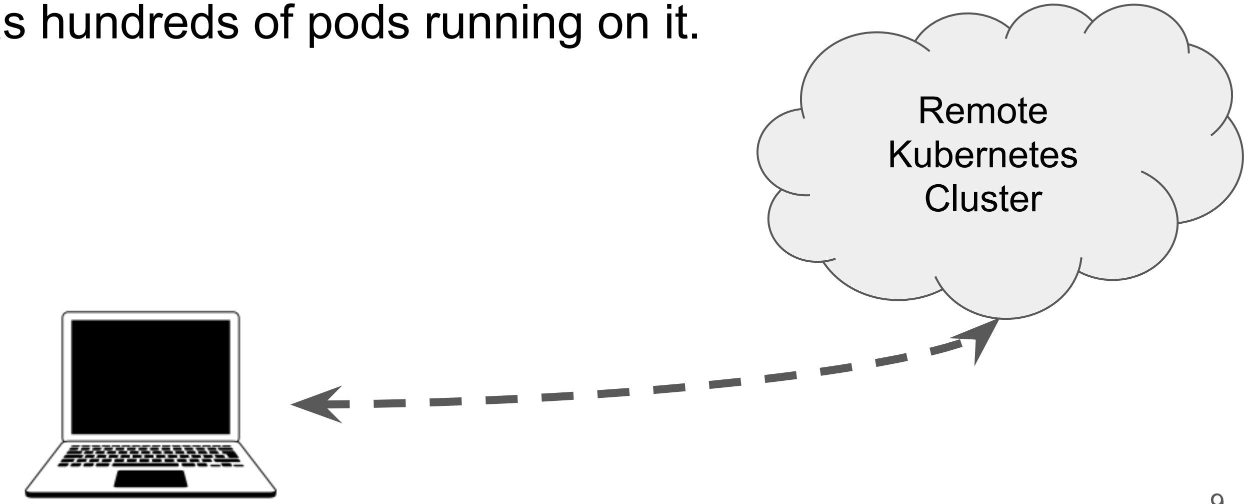


Informer Demo Setup

- Environment: Cluster running on local machine
  - 2 compute nodes
    - 1 Master node: Kubernetes control plane
    - 1 worker node
      - 16 virtual cores
- Tools:
  - Kind
  - Docker
- Task:
  - Deploy 4 pods scheduled by KubeFlux, each pod requires 8 cpu cores
- Goal
  - Demonstrate job cancellation feature with 4 succeeded pods
  - Demonstrate informer with 4 failed pods

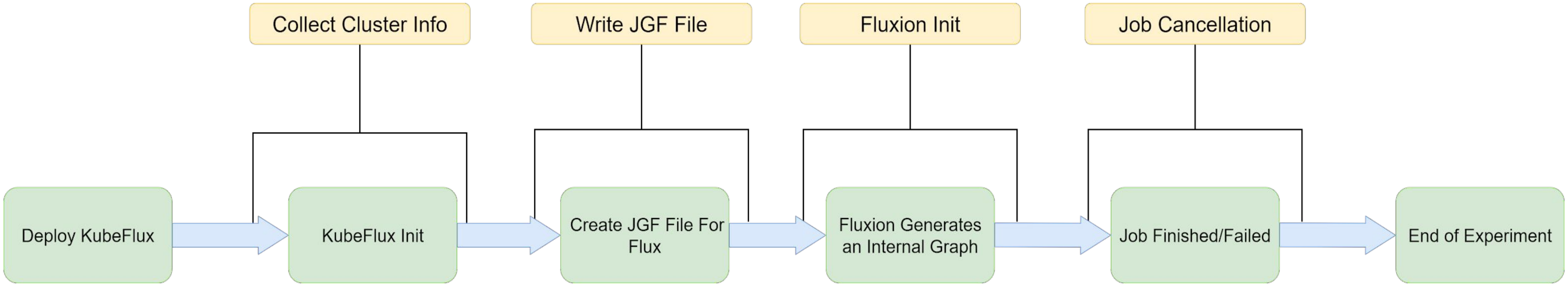
Experiment - KubeFlux Operations Time Consumption

- Deploy Pi calculation program on a remote cluster
  - Originally planned with the GROMACS application test, but it was broken
- The cluster has 8 accessible worker nodes
- Each worker node has: 4 cpu cores, 16 Gb memory
- The cluster already has hundreds of pods running on it.



Performance Metrics

- Collect Cluster Information
- Write JGF (Json Graph Format) File
- Fluxion Initialization
- Job Cancellation



Experiment - Result

Overhead Measurements in Experiments (Unit: Second)					
No	Resource Graph Creation				Job Cancellation
	Collect Cluster Information	Write JGF File	Fluxion Initialization	Overall Time Consumption	
1	2.15588139	0.00185015	0.002944827	2.160676367	0.000160137
2	0.424259821	0.001822241	0.003250035	0.429332097	0.000161866
3	0.281901809	0.002125131	0.004601823	0.288628763	0.000138845
4	0.382038727	0.006396838	0.003113534	0.391549099	0.000142303
5	0.211644054	0.004054272	0.003107828	0.218806154	0.000151261
6	0.45694305	0.001359202	0.003051238	0.46135349	0.000130882
7	0.216843598	0.007000077	0.003323509	0.227167184	0.000113033

The challenge of Co-scheduling

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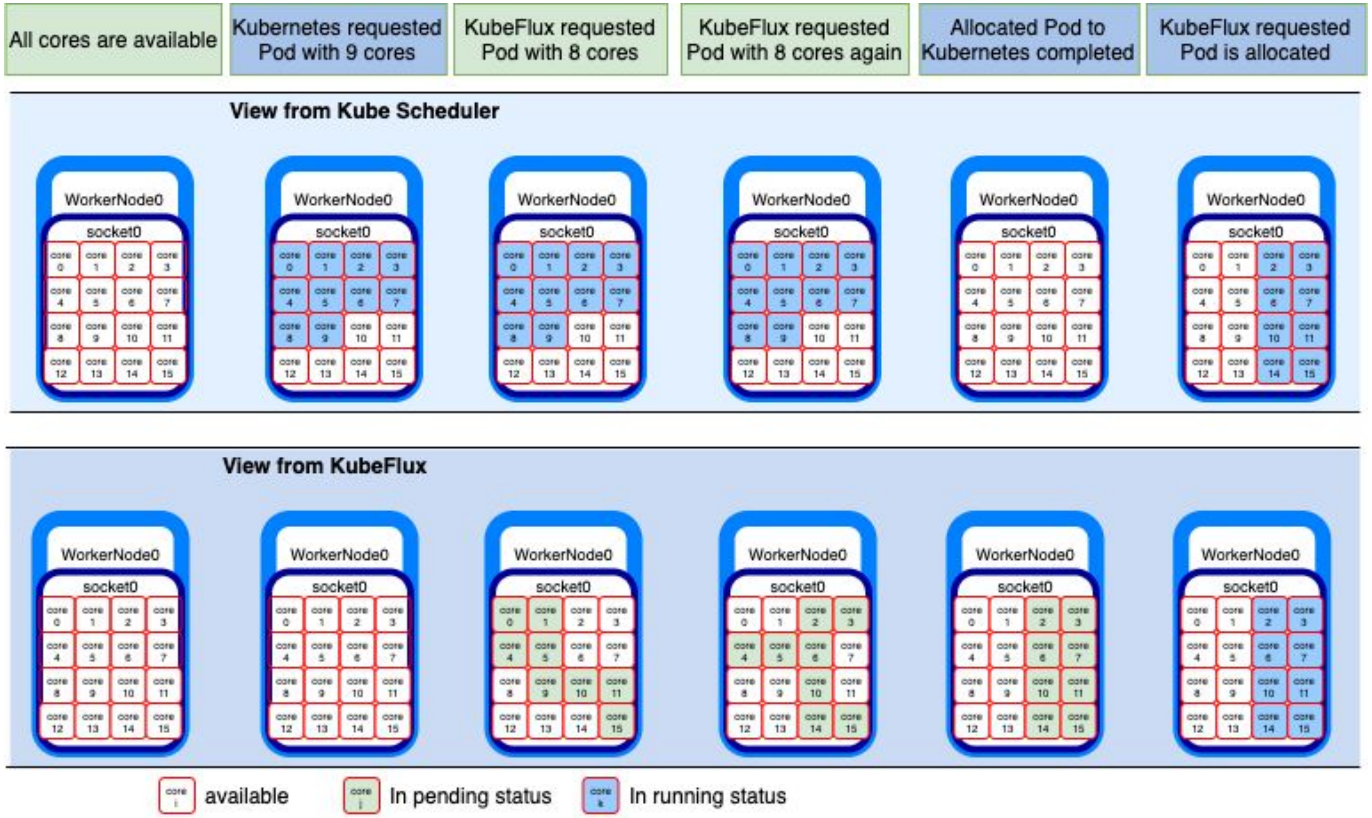
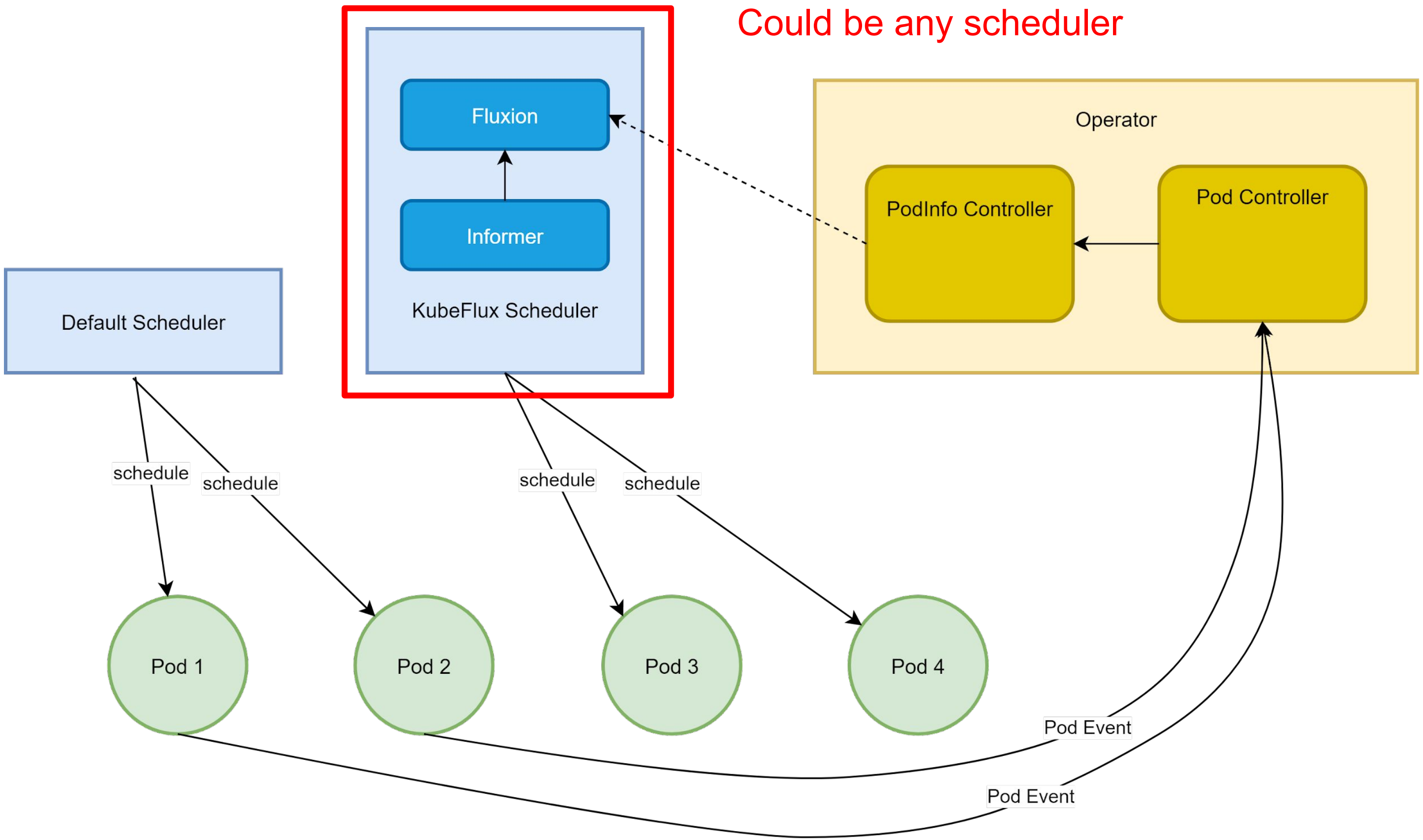


Main conceptual challenges

- Abstraction: Enabling co-scheduling of any two scheduler plugins.
  - The solution should offer a representation of how it records changes
  - Schedulers wanting to make use of co-scheduling to become aware of other schedulers can translate the changes recorded by the operator and update their own internal state accordingly.
  - Each component participating in co-scheduling is specific to a certain level. The interfaces have to be prescriptive of how to implement co-scheduling but not too restrictive.

Potential Solution: Pod Controller

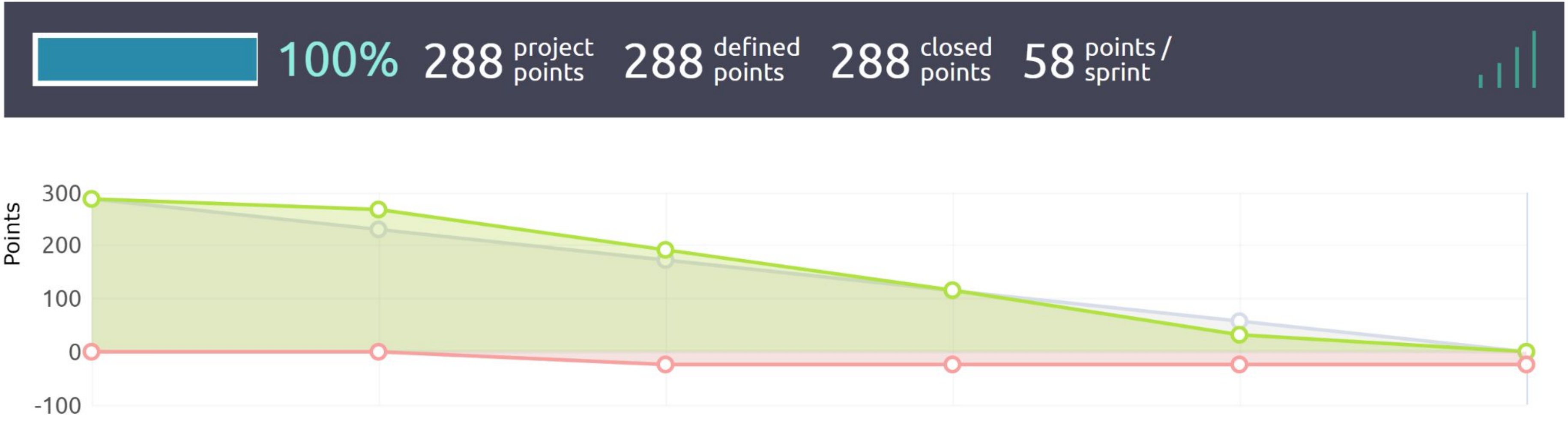


Main technical challenges

- Kubernetes has 3 different ways of specifying pod resource needs.
  - Priority 1: Guaranteed Pod
  - Priority 2: Burstable Pod
  - Priority 3: Best-Effort Pod
- Resources usage fluctuations
- Imperative HPC management philosophy doesn’t align with the declarative K8s management philosophy

Conclusion

- Studied about Kubernetes, Flux and Golang basics
- Implemented an informer, which is now part of the KubeFlux plugin
- Started the implementation of an operator
- Performed analysis on the time consumed by the informer



Future Scope

Extend the project to help KubeFlux become a competent HPC scheduling solution for Kubernetes:

- Designing a standard process for synchronizing a plug-in scheduler's internal state with the Kubernetes cluster state
    - Getting a proper figure of resource utilization from running pods (translating Kubernetes cpu measurements to tangible info)
    - Designing interface with a generic representation of the kubernetes cluster state that plug-in schedulers can access.

Thank You!