Kubernetes 调度器详解

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Agenda

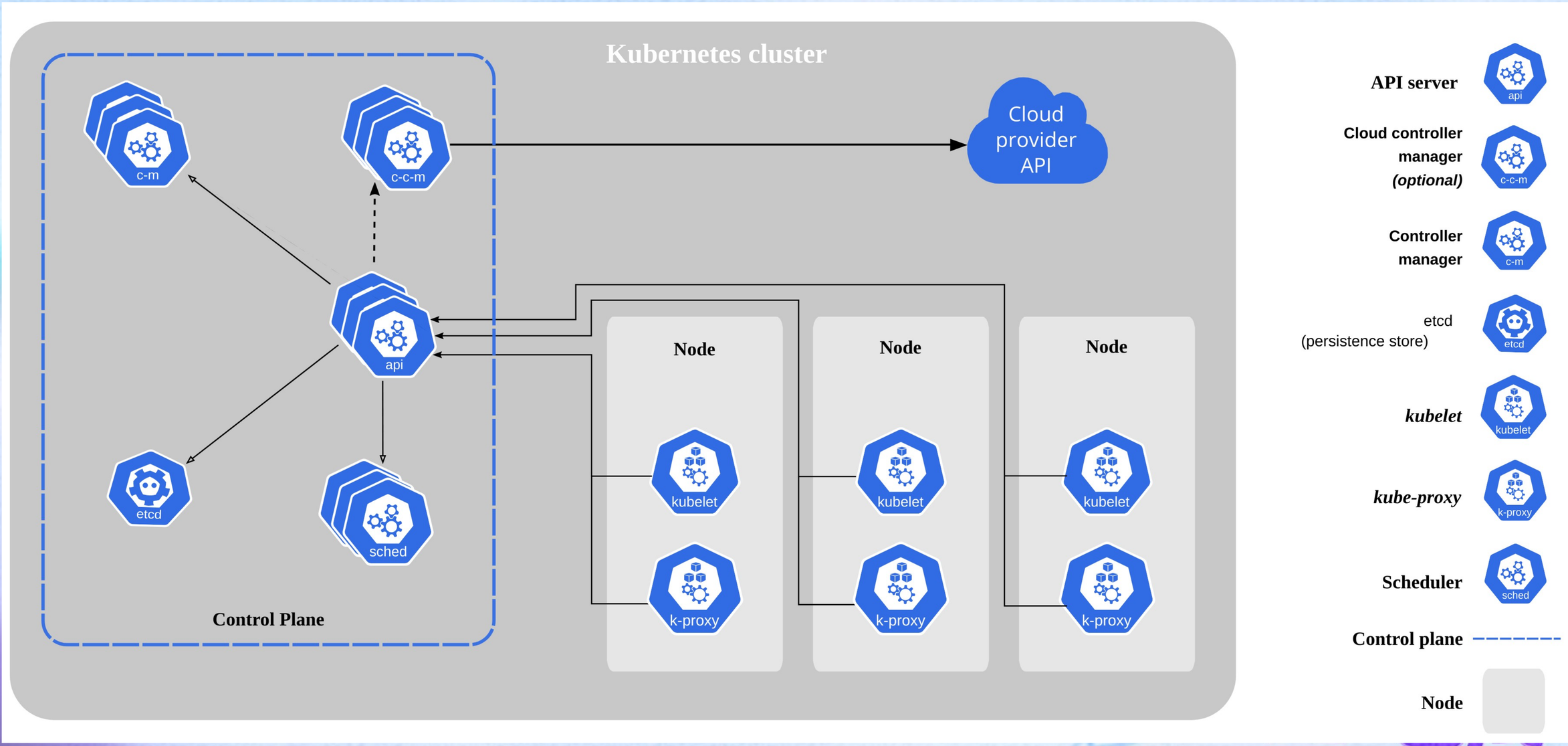
- Kubernetes 调度器的发展历史
- Kubernetes 如何进行调度
- 如何自定义 Kubernetes 调度器
- Kubernetes v1.26 调度方面的改变

Kubernetes 调度器的发展历史

前置知识

- Pod 是 Kubernetes 中最小的调度单元
- 一个 Pod 中可以包含一个或多个 container
- Pod 运行在 Node 上
- Pod 中包含的 container 运行需要消耗资源
  - CPU
  - 内存
  - 存储
  - 扩展资源
- Pod 存在优先级的区别
- Pod 可以被单独创建也可以由其他资源控制器创建

Kubernetes 概览

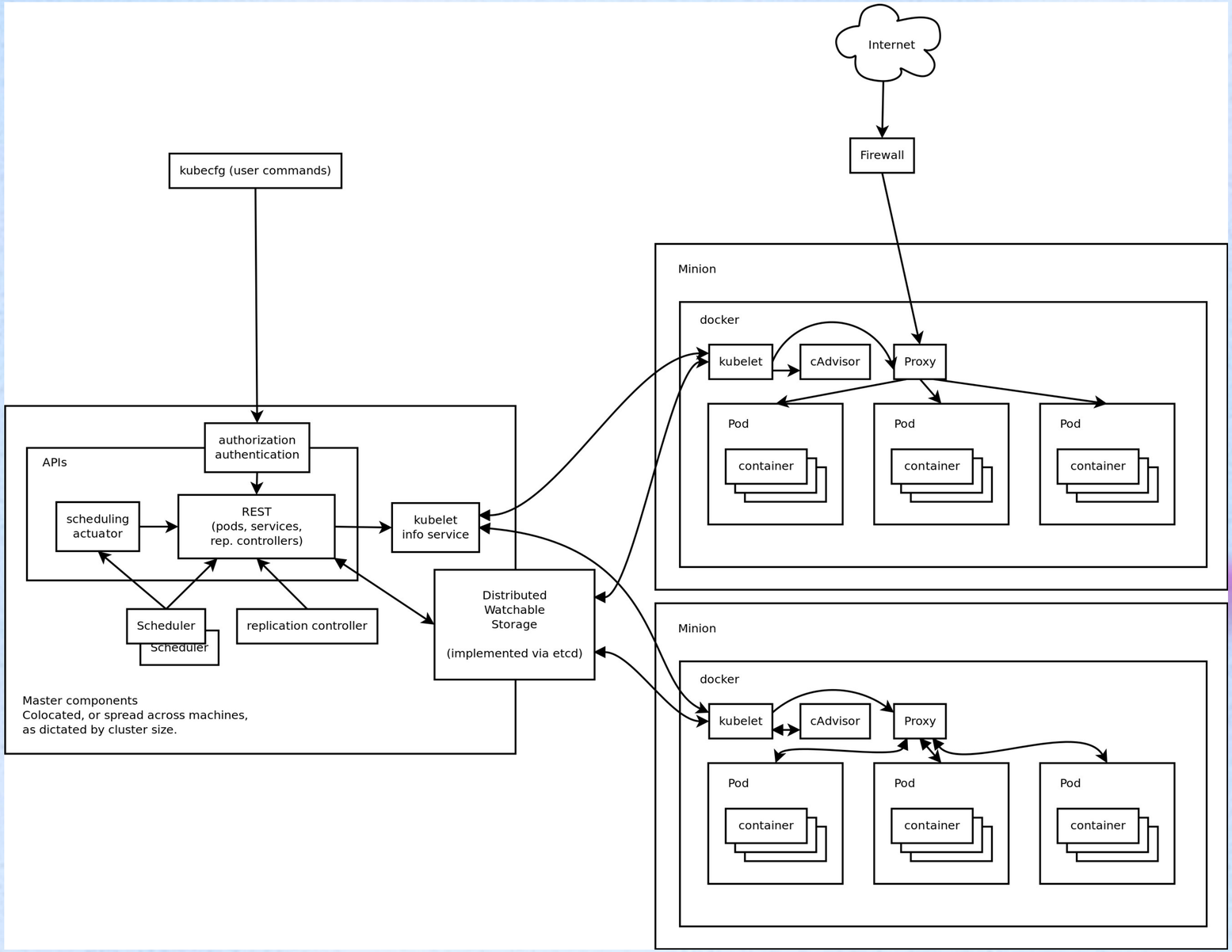


什么是调度

- 将新创建的 Pod 与 Node 进行关联
  - Node 可用性
  - 资源容量
  - 亲和性 / 反亲和性
  - 拓扑感知
  - taint
  - ...

最简单的 Scheduler 实现

- 随机（random）
- 轮训（roundrobin）



随机（random）

- 随机数
- 取余

```
// Schedule schedules a pod on a random machine which matches its requirement.
func (s *RandomFitScheduler) Schedule(pod api.Pod, minionLister MinionLister) (string, error) {
    machines, err := minionLister.List()
    if err != nil {
        return "", err
    }
    machineToPods := map[string][]api.Pod{}
    // TODO: perform more targeted query...
    pods, err := s.podLister.ListPods(labels.Everything())
    if err != nil {
        return "", err
    }
    for _, scheduledPod := range pods {
        host := scheduledPod.CurrentState.Host
        machineToPods[host] = append(machineToPods[host], scheduledPod)
    }
    var machineOptions []string
    for _, machine := range machines {
        podFits := true
        for _, scheduledPod := range machineToPods[machine] {
            for _, container := range pod.DesiredState.Manifest.Containers {
                for _, port := range container.Ports {
                    if port.HostPort == 0 {
                        continue
                    }
                    if s.containsPort(scheduledPod, port) {
                        podFits = false
                    }
                }
            }
        }
        if podFits {
            machineOptions = append(machineOptions, machine)
        }
    }
    if len(machineOptions) == 0 {
        return "", fmt.Errorf("failed to find fit for %#v", pod)
    }
    s.randomLock.Lock()
    defer s.randomLock.Unlock()
    return machineOptions[s.random.Int()%len(machineOptions)], nil
}
```

分阶段调度

- 预选（Predicate）
  - 是否满足基本条件
- 优选（Priorities）
  - 是否为最佳选择

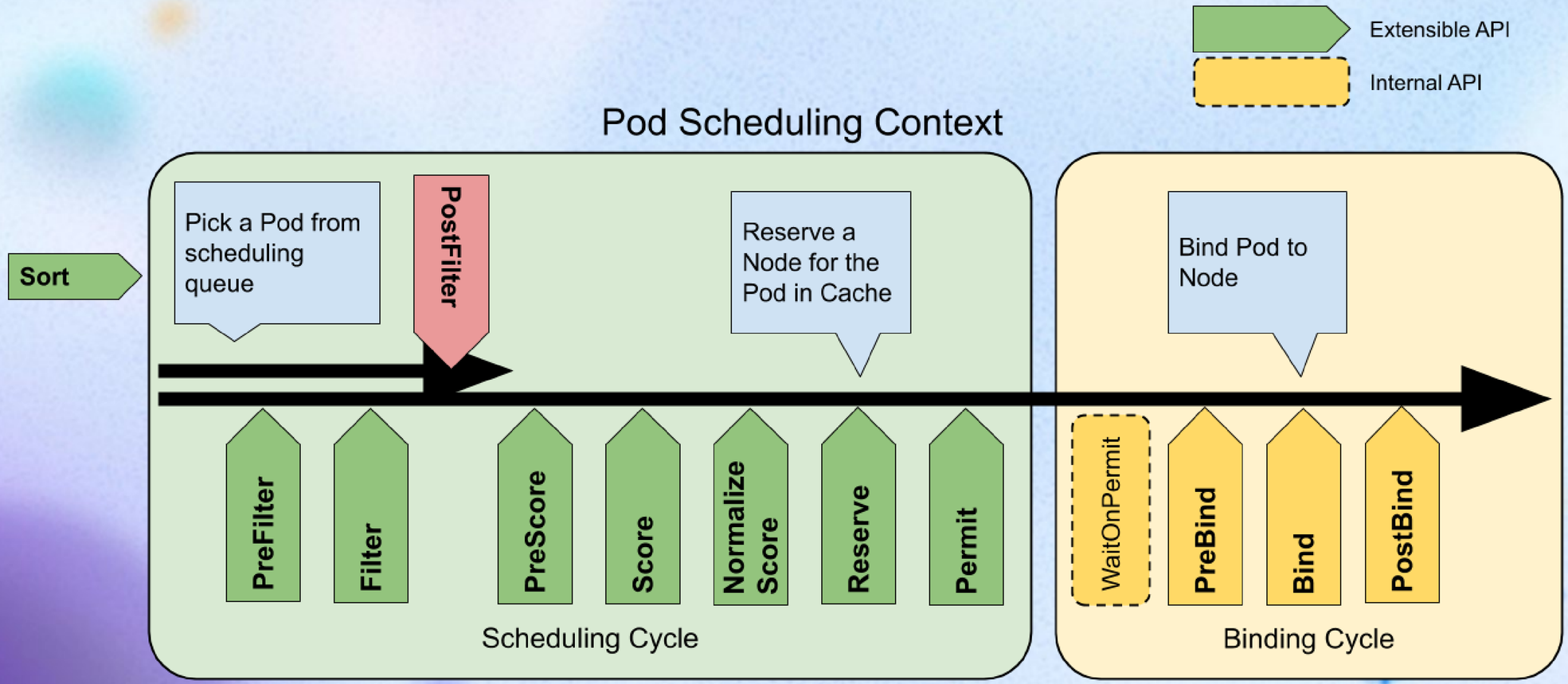
可扩展的 Scheduler （ extender ）

- 使用 webhook 方式进行扩展
  - 扩展点有限
  - 需要 JSON 编解码（效率低）
  - 无法及时终止（交互）
  - 不能使用 Scheduler 的缓存

```
{
  "predicates": [
    {
      "name": "HostName"
    },
    {
      "name": "MatchNodeSelector"
    },
    {
      "name": "PodFitsResources"
    }
  ],
  "priorities": [
    {
      "name": "LeastRequestedPriority",
      "weight": 1
    }
  ],
  "extenders": [
    {
      "urlPrefix": "http://127.0.0.1:12345/api/scheduler",
      "filterVerb": "filter",
      "enableHttps": false
    }
  ]
}
```

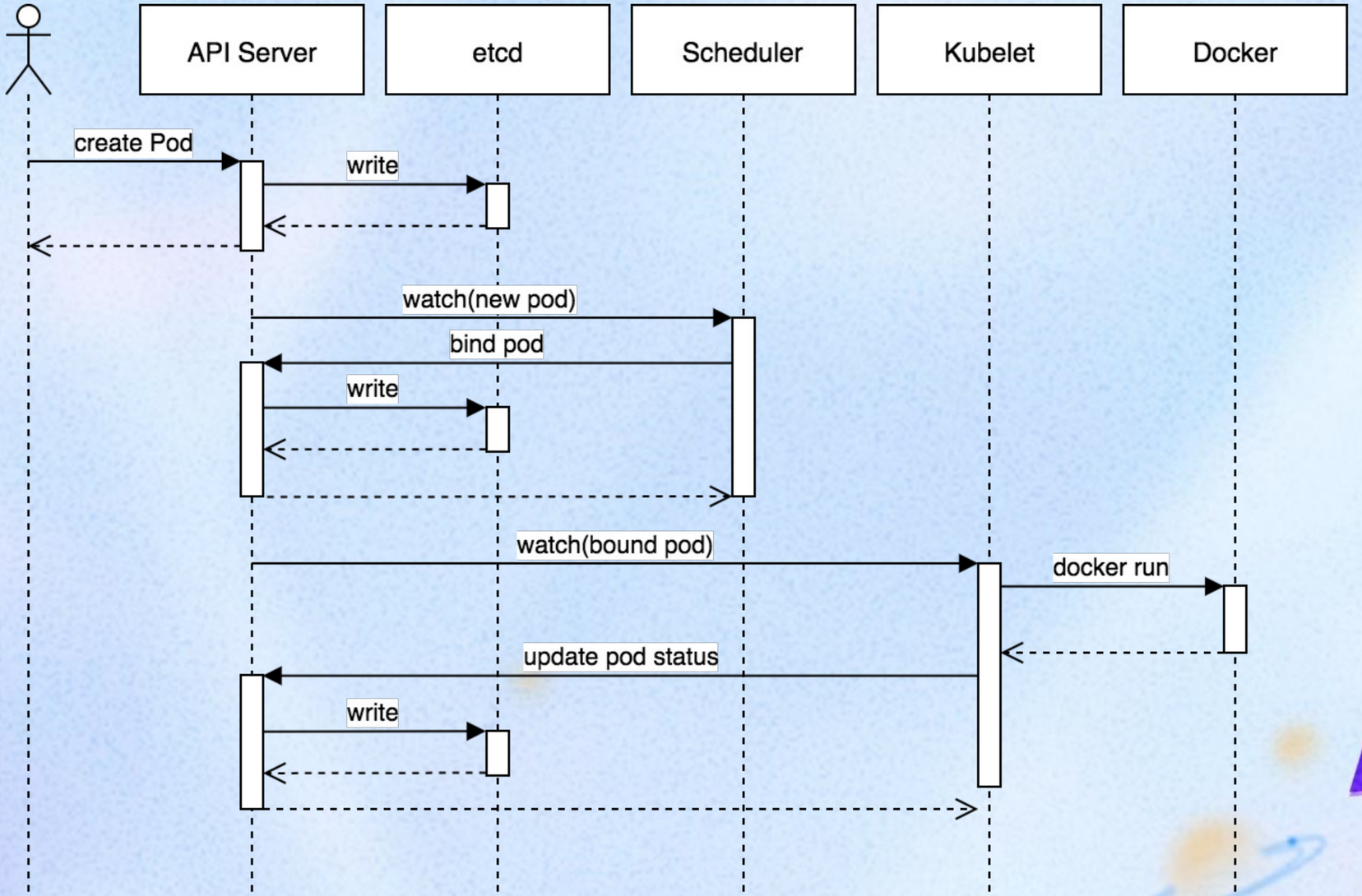
可扩展的 Scheduling Framework

- 扩展点丰富
- 在框架中提供扩展点



Kubernetes 如何进行调度

创建 Pod 的过程



Ref: https://sourl.cn/VhykU4

schedulePod

```
311 func (sched *Scheduler) schedulePod(ctx context.Context, fwk framework.Framework, state *framework.CycleState, pod *v1.Pod) (result ScheduleResult, err error) {
  1     if err := sched.Cache.UpdateSnapshot(sched.nodeInfoSnapshot); err != nil {
  2         return result, err
  3     }
  4     if sched.nodeInfoSnapshot.NumNodes() == 0 {
  5         return result, ErrNoNodesAvailable
  6     }
  7     feasibleNodes, diagnosis, err := sched.findNodesThatFitPod(ctx, fwk, state, pod)
  8     if err != nil {
  9         return result, err
 10     }
 11     if len(feasibleNodes) == 0 {
 12         return result, &framework.FitError{
 13             Pod:          pod,
 14             NumAllNodes: sched.nodeInfoSnapshot.NumNodes(),
 15             Diagnosis:    diagnosis,
 16         }
 17     }
 18     // When only one node after predicate, just use it.
 19     if len(feasibleNodes) == 1 {
 20         return ScheduleResult{
 21             SuggestedHost:  feasibleNodes[0].Name,
 22             EvaluatedNodes: 1 + len(diagnosis.NodeToStatusMap),
 23             FeasibleNodes:  1,
 24         }, nil
 25     }
 26     priorityList, err := prioritizeNodes(ctx, sched.Extenders, fwk, state, pod, feasibleNodes)
 27     if err != nil {
 28         return result, err
 29     }
 30     host, err := selectHost(priorityList)
 31     trace.Step("Prioritizing done")
 32
 33     return ScheduleResult{
 34         SuggestedHost:  host,
 35         EvaluatedNodes: len(feasibleNodes) + len(diagnosis.NodeToStatusMap),
 36         FeasibleNodes:  len(feasibleNodes),
 37     }, err
 38 }
```

策略

- 存储
- Node 匹配度
- Pod 拓扑
- 资源水位
- Node 亲和 / 反亲和
- Pod 亲和 / 反亲和
- ...

如何自定义 Kubernetes 调度器

自定义方式

- 修改 kube-scheduler 调度规则并重新编译
- 实现独立的 scheduler 组件，代替或和 kube-scheduler 共同使用
- 实现 scheduler extender
- Scheduling Framework

扩展配置

- kube-scheduler 可接受多个配置文件
- https://github.com/kubernetes-sigs/scheduler-plugins/

```yaml
apiVersion: kubescheduler.config.k8s.io/v1beta2
kind: KubeSchedulerConfiguration
leaderElection:
  leaderElect: false
clientConnection:
  kubeconfig: "REPLACE_ME_WITH_KUBE_CONFIG_PATH"
profiles:
- schedulerName: default-scheduler
  plugins:
    score:
      enabled:
      - name: PodState
```

初始化 plugin

- 选择扩展点
- 注册名称

```go
package podstate

import (
    "context"
    "fmt"
    "math"

    "k8s.io/api/core/v1"
    "k8s.io/apimachinery/pkg/runtime"
    "k8s.io/kubernetes/pkg/scheduler/framework"
)

type PodState struct {
    handle framework.Handle
}

var _ = framework.ScorePlugin(&PodState{})

// Name is the name of the plugin used in the Registry and configurations.
const Name = "PodState"

func (ps *PodState) Name() string {
    return Name
}

// core logic

// New initializes a new plugin and returns it.
func New(_ runtime.Object, h framework.Handle) (framework.Plugin, error)
{   return &PodState{handle: h}, nil
}
```

核心逻辑

- 越多终止状态的 Node 份数越高
- 返回最终打分结果

```go
// Score invoked at the score extension point.
func (ps *PodState) Score(ctx context.Context, state *framework.CycleState, pod *v1.Pod, nodeName string)
(int64, *framework.Status) {
    nodeInfo, err := ps.handle.SnapshotSharedLister().NodeInfos().Get(nodeName)
    if err != nil {
        return 0, framework.NewStatus(framework.Error, fmt.Sprintf("getting node %q from Snapshot: %v",
nodeName, err))
    }

    // pe.score favors nodes with terminating pods instead of nominated pods
    // It calculates the sum of the node's terminating pods and nominated pods
    return ps.score(nodeInfo)
}

// ScoreExtensions of the Score plugin.
func (ps *PodState) ScoreExtensions() framework.ScoreExtensions {
    return ps
}

func (ps *PodState) score(nodeInfo *framework.NodeInfo) (int64, *framework.Status) {
    var terminatingPodNum, nominatedPodNum int64
    // get nominated Pods for node from nominatedPodMap
    nominatedPodNum = int64(len(ps.handle.NominatedPodsForNode(nodeInfo.Node().Name)))
    for _, p := range nodeInfo.Pods {
        // Pod is terminating if DeletionTimestamp has been set
        if p.Pod.DeletionTimestamp != nil {
            terminatingPodNum++
        }
    }
    return terminatingPodNum - nominatedPodNum, nil
}

func (ps *PodState) NormalizeScore(ctx context.Context, state *framework.CycleState, pod *v1.Pod, scores
framework.NodeScoreList) *framework.Status {
    // Find highest and lowest scores.
    var highest int64 = -math.MaxInt64
    var lowest int64 = math.MaxInt64
    for _, nodeScore := range scores {
        if nodeScore.Score > highest {
            highest = nodeScore.Score
        }
        if nodeScore.Score < lowest {
            lowest = nodeScore.Score
        }
    }

    // Transform the highest to lowest score range to fit the framework's min to max node score range.
    oldRange := highest - lowest
    newRange := framework.MaxNodeScore - framework.MinNodeScore
    for i, nodeScore := range scores {
        if oldRange == 0 {
            scores[i].Score = framework.MinNodeScore
        } else {
            scores[i].Score = ((nodeScore.Score - lowest) * newRange / oldRange) + framework.MinNodeScore
        }
    }

    return nil
}
```

Kubernetes v1.26 调度方面的改变

增加 Pod 调度就绪机制

- KEP 3521
- 不再是创建后即调度
- 在 Pod 所需的依赖就绪后再开始进行调度
- 适用场景：需要存储等外置依赖时候

总结

- 调度是 Kubernetes 的核心能力之一
- 良好的 / 适当的调度逻辑可辅助业务
- 降本增效
- 基于机器学习的调度也会有一些发展

Microsoft® Most Valuable Professional

Thanks!