Kubenettes ↔ HTCSS

Understanding the possibilities

Brian Bockelman, 25 September 2024

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Kubernetes

Kubernetes is an open-source container orchestration system.

What does this mean?

- **Open-source**: Started by Google engineers, now developed by a large community and run under the auspices of the Cloud Native Computing Foundation.
- **Container**: Atomic unit of functionality, the “pod”, is composed of one or more containers working together.
- **Orchestration**: A single object can tie together multiple aspects of a service – including dependencies (e.g., database) and network requirements (firewall, DNS).

Kubernetes originates from the Greek κυβερνήτης (kubernḗtēs), meaning governor, 'helmsman' or 'pilot'.

Let’s skip the boring parts

Kubernetes Lingo:

- A **custom resource definition** (CRD) is an custom object type that can extend Kubernetes.
- An **operator** is an extension to Kubernetes that manages custom objects for applications.

- You can run a static HTCondor pool within a Kubernetes cluster:
  - HTCSS team publishes a reference central manager, AP, and EP container image.
  - Going from container image to a deployment is left as an exercise for the user.
- The OSPool runs its central manager inside two Kubernetes clusters.
  - We use a “GitOps” methodology, using a shared base deployment inside a git repository. When changes are committed to the base, they are synchronized by the Flux **operator** to the production clusters.
- However, a statically-sized pool is rather boring: it’s a fairly “vanilla” deployment of an application on Kubernetes.
  - *Still, it’d be nice if we packaged this in a Helm chart.* ☹

Boring Case Study: OSPool Backfill

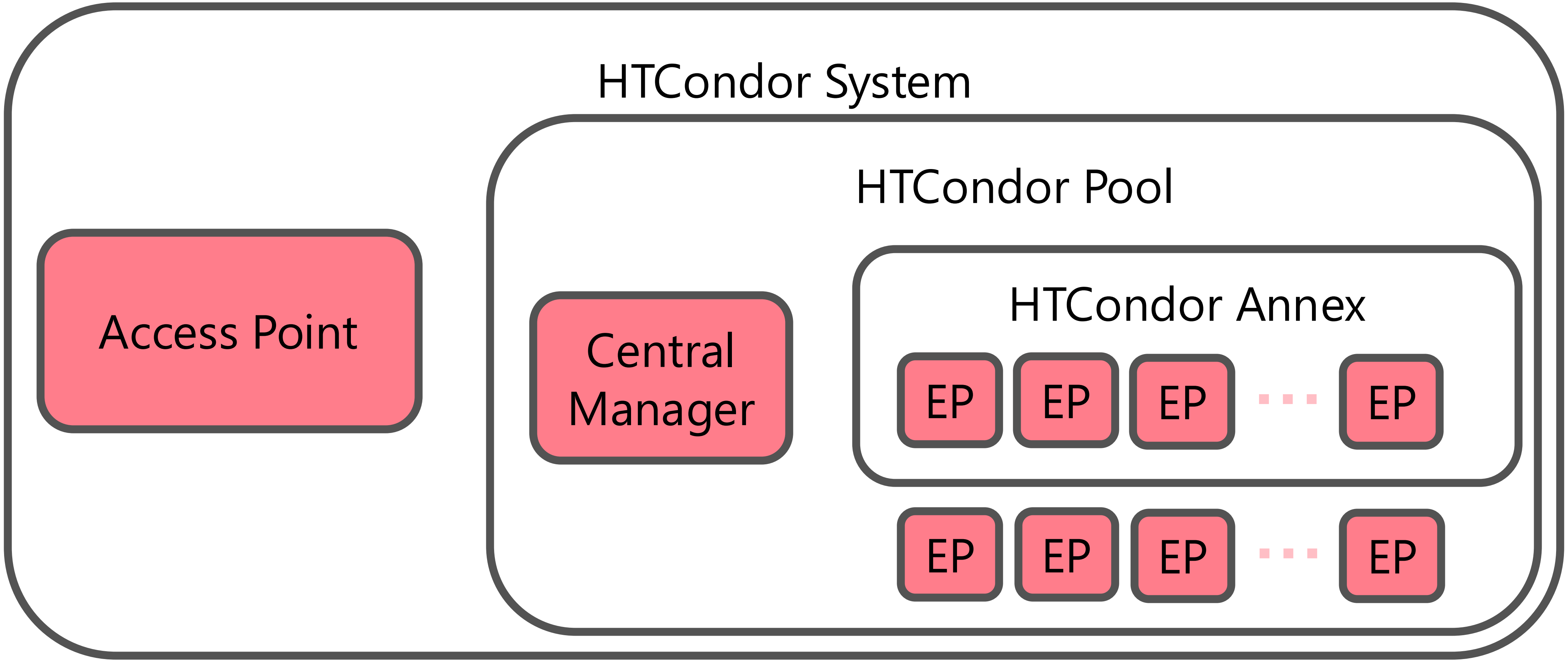
- The OSPool operators publish a “backfill container” image.
  - Given a token, the container will start an EP that connects to the OSPool.
- Cluster administrators can setup a Kubernetes deployment that launches enough pods to saturate the cluster.
  - Set the priority low enough so these are always preempted if another pod needs to run.
- Great for otherwise-idle resources!
  - Not great if you care that OSPool may run out of jobs for your EPs.
  - Not great if you want to balance resources across multiple pools.

Backfill is boring.

What about dynamic workloads?

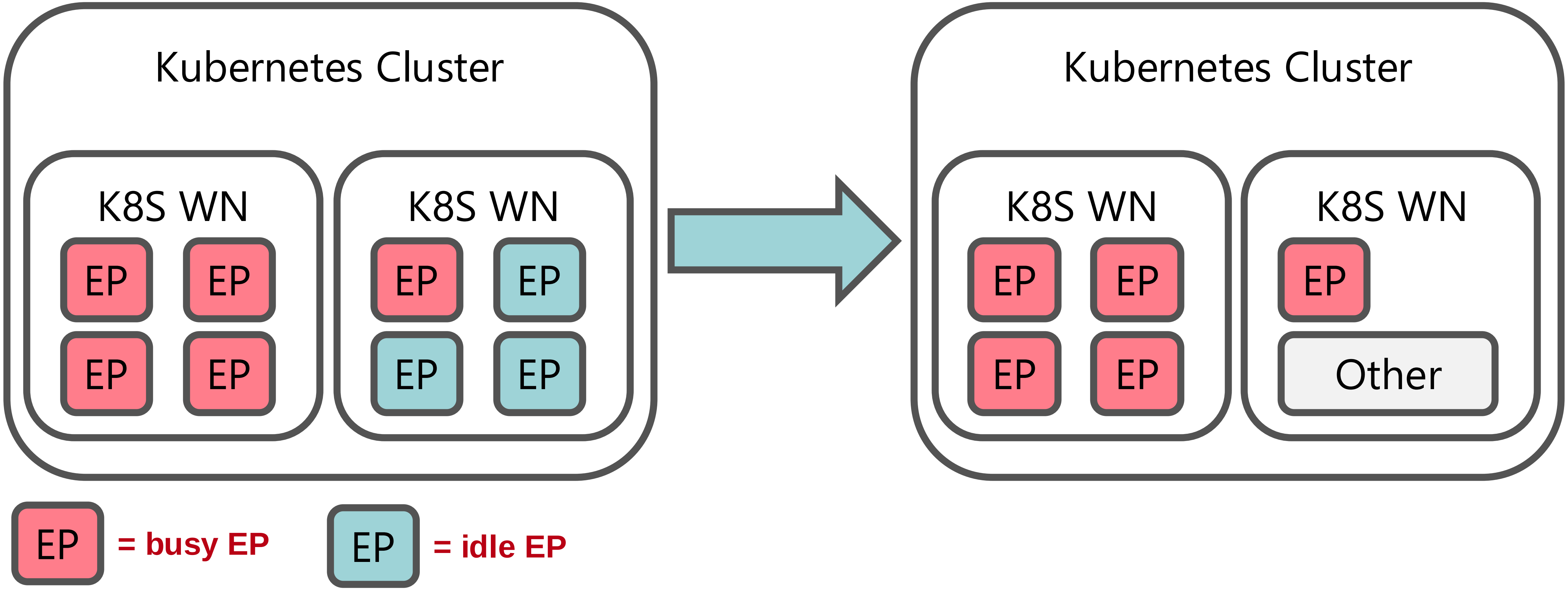
Something interesting – dynamic pools and annexes

- We want the HTCondor pool to grow and shrink based on demand or scheduling policy.



Desired Behavior

Shrink when EPs are idle, grow when there is demand – give Kubernetes scheduler a chance to make decisions!



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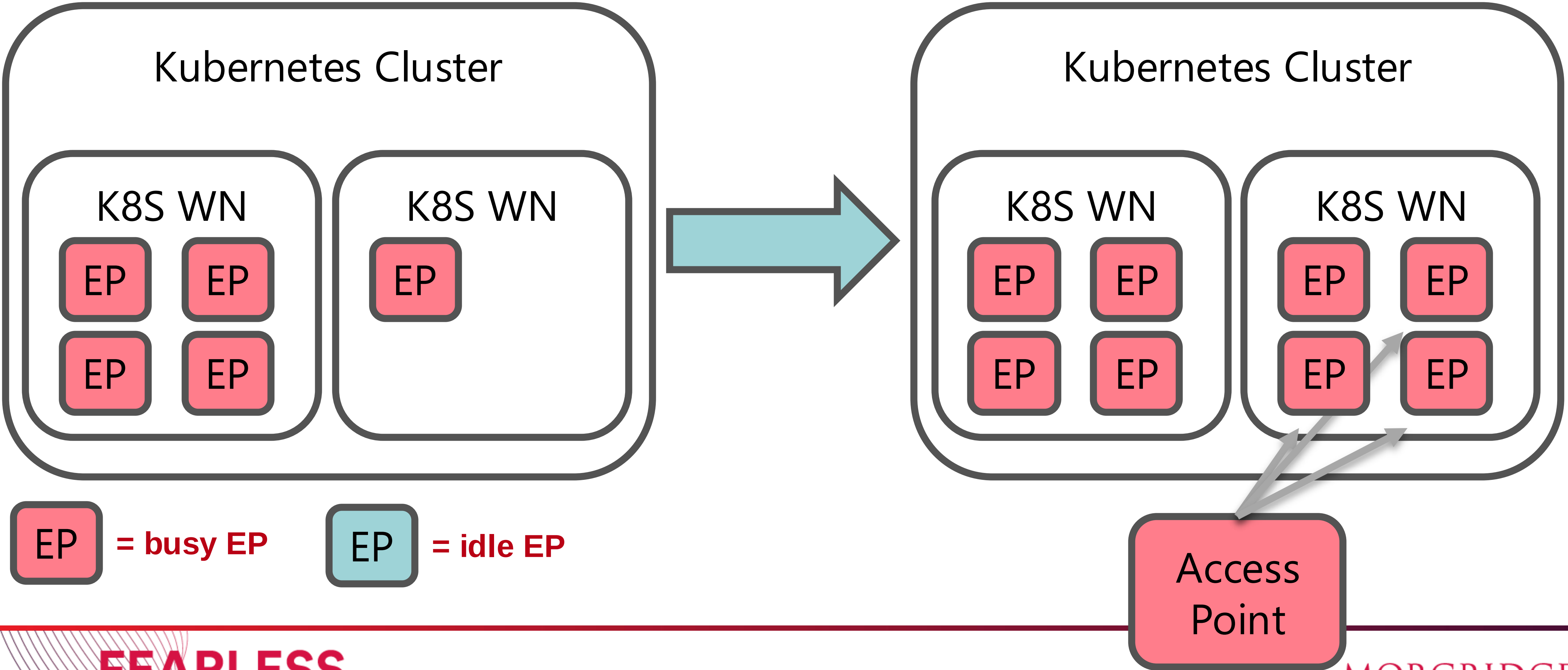
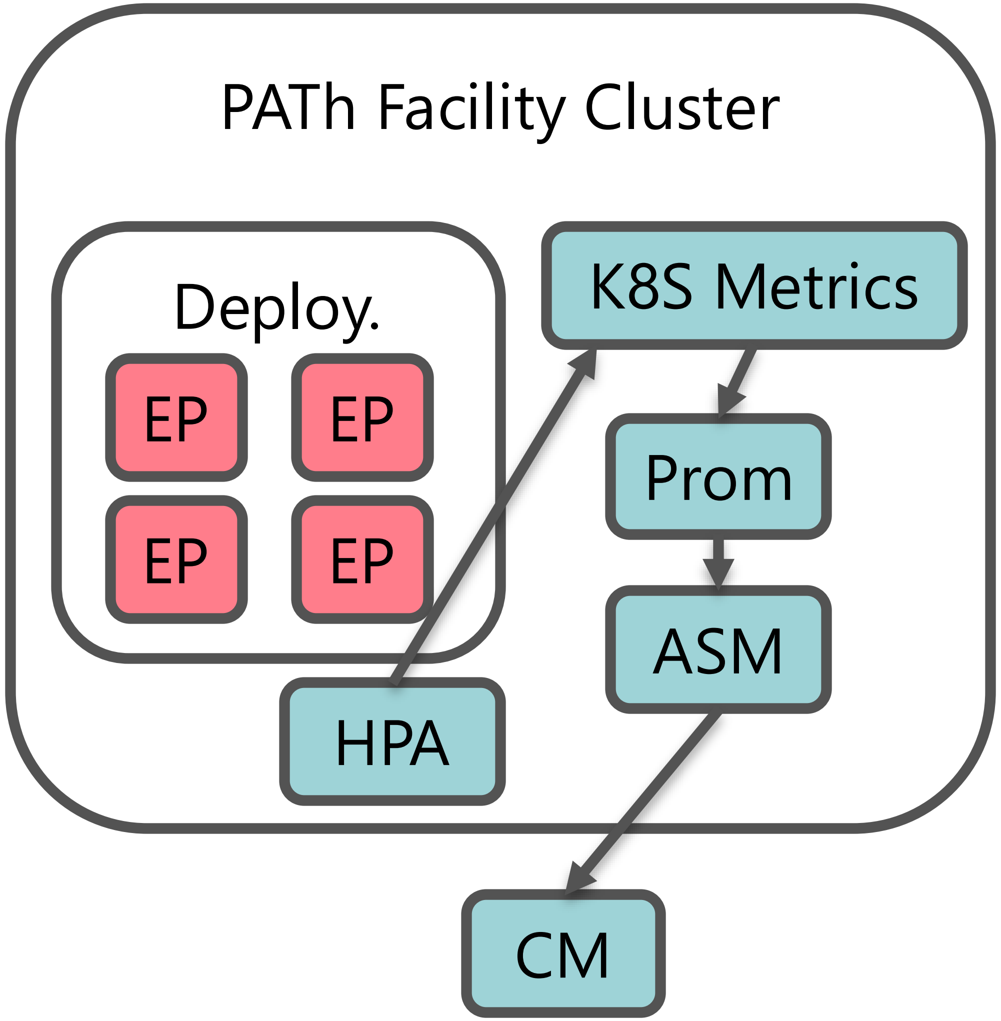


Two starting models for Kubernetes

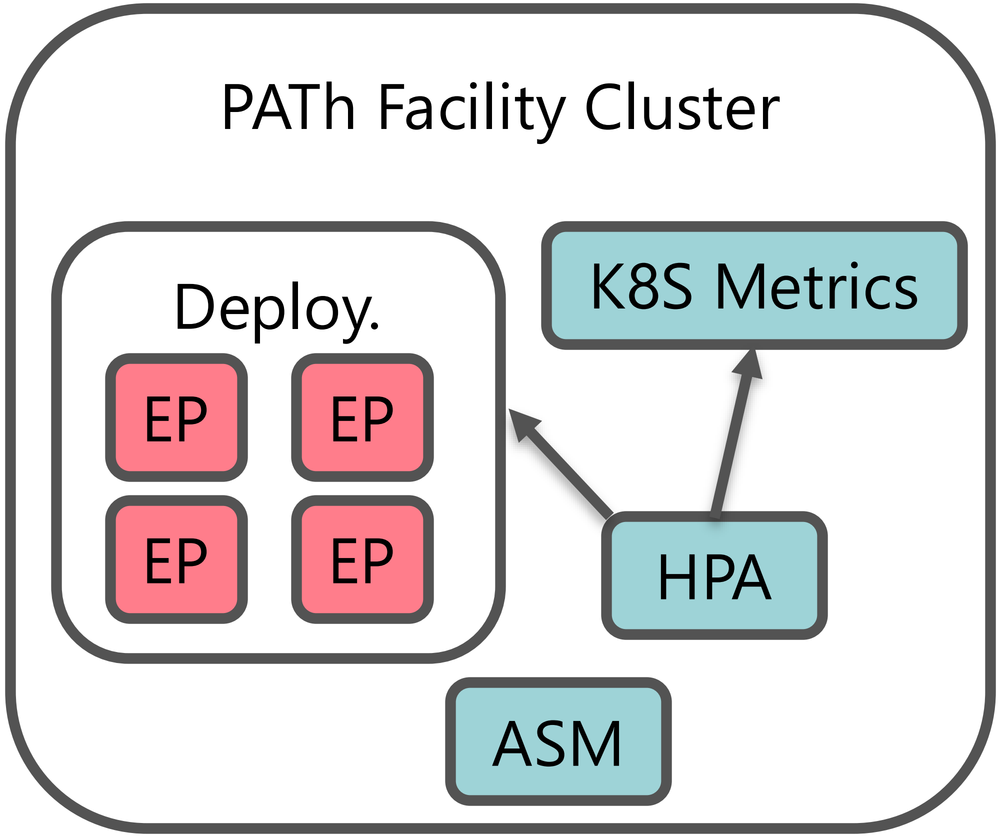
- "**Dynamic deployment**": Use the Kubernetes "**deployment**" object which manages a configured set of identical EP pods.
  - Kubernetes will automatically restart any pod in a deployment that dies.
  - The "Horizontal Pod Autoscaler" (HPA) component will scale the deployment up and down based on need.
- "**Glidein model**": Have a standalone service create a Kubernetes "**job**" / pod.
  - The service creates according to the need it detects.
  - Ephemeral: when the K8S job finishes (or errors), the pod goes away.

Case Study: PATh Facility



- At the PATh Facility cluster, we took the “dynamic deployment” route.
- A central service, the ‘htcondor-autoscale-manager’ (ASM), queries the collector for the state of the EPs and creates an “occupancy metric”:
  - <1 indicates EPs are idle and need to be shut down
  - >1 indicates
- The Prometheus operator scrapes the ASM’s metrics.
  - The Prometheus adapter converts the Prometheus metric into the Kubernetes metric system.

PATh Facility – Scaling up and down



- The Horizontal Pod Autoscaler (HPA) will adjust the number of pods in the deployment to bring the occupancy metric to 1.
- For scale-down, **how does Kubernetes know which pod to preempt?**
  - Every cycle, the ASM calculates a ‘preemption cost’ based on the work that would be lost on preemption.
  - The ASM annotates each pod with the preemption cost.
  - The Kubernetes scheduler will select the lower-cost pod, preempting the idle one.
    - Otherwise, it selects randomly!

PATh Facility - Scaling up

- **Q**: How does the ASM know when a new EP is needed?

  A: Offline ads!
- The ASM will take a snapshot of an EP's slot ad and advertise it to the collector as a "fake" offline slot.
  - Assumption: all EPs in the same deployment are "the same".
- When the negotiator has a match for the offline ad, it will annotate the ad.
  - This annotation says "**I could have used this slot if it was online**"
- During next ASM cycle, it will raise the occupancy metric and a new pod will launch.

Impact: No configuration, no ClassAd expressions; <u>the negotiator does all the work!</u>

PATh Facility – Upsides & Downsides

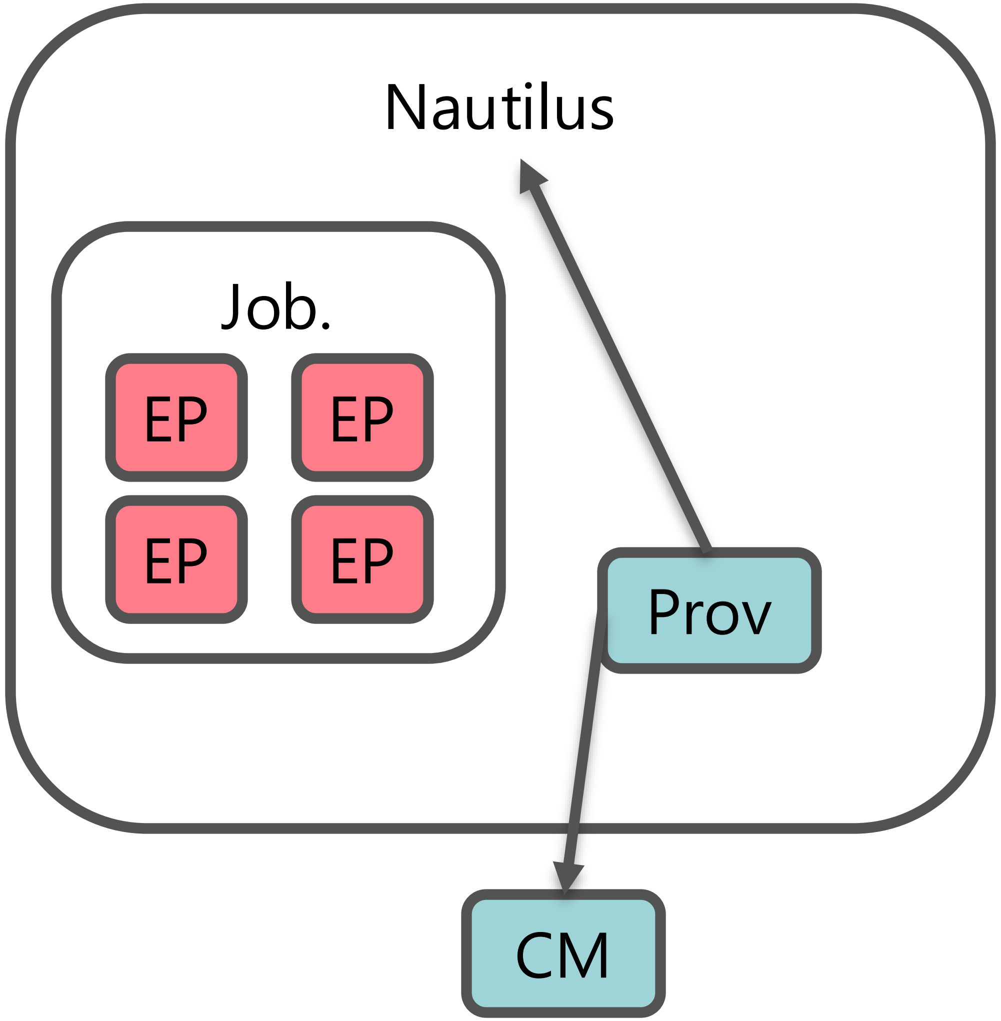
What's wrong with this model?

- **Pod auto-restarts when idle**: bad at releasing resources when they are incorrectly requested.
  - Prevents K8S from pulling updates automatically
- **Requires additional operators**, even in simple configuration:
  - Functionality requires a Prometheus setup and the Prometheus Adapter (latter is installed at the cluster level).
- "Control loop" grows or shrinks a single node at a time. Slow ramp-up for shifting workloads.

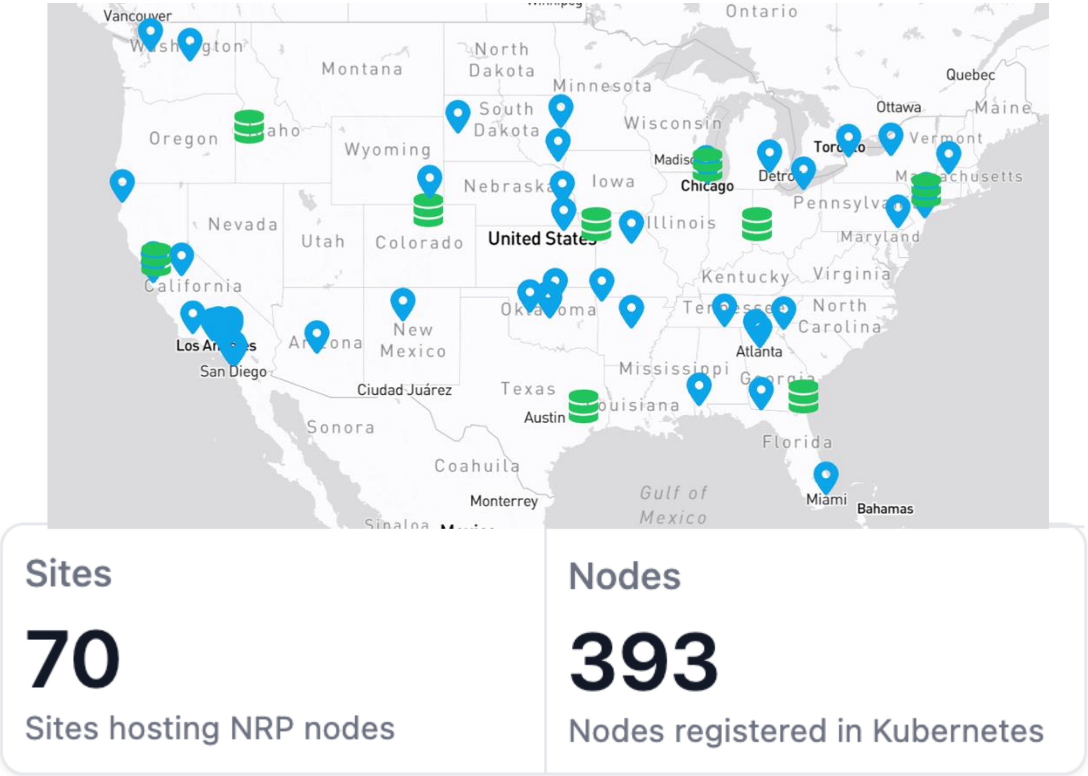
Advantages?

- Minimal ClassAd configuration: relies solely on the negotiator to indicate load.

Case Study: National Research Platform



- The National Research Platform (NRP) project operates a stretched Kubernetes cluster, Nautilus, with hosts spanning the nation.



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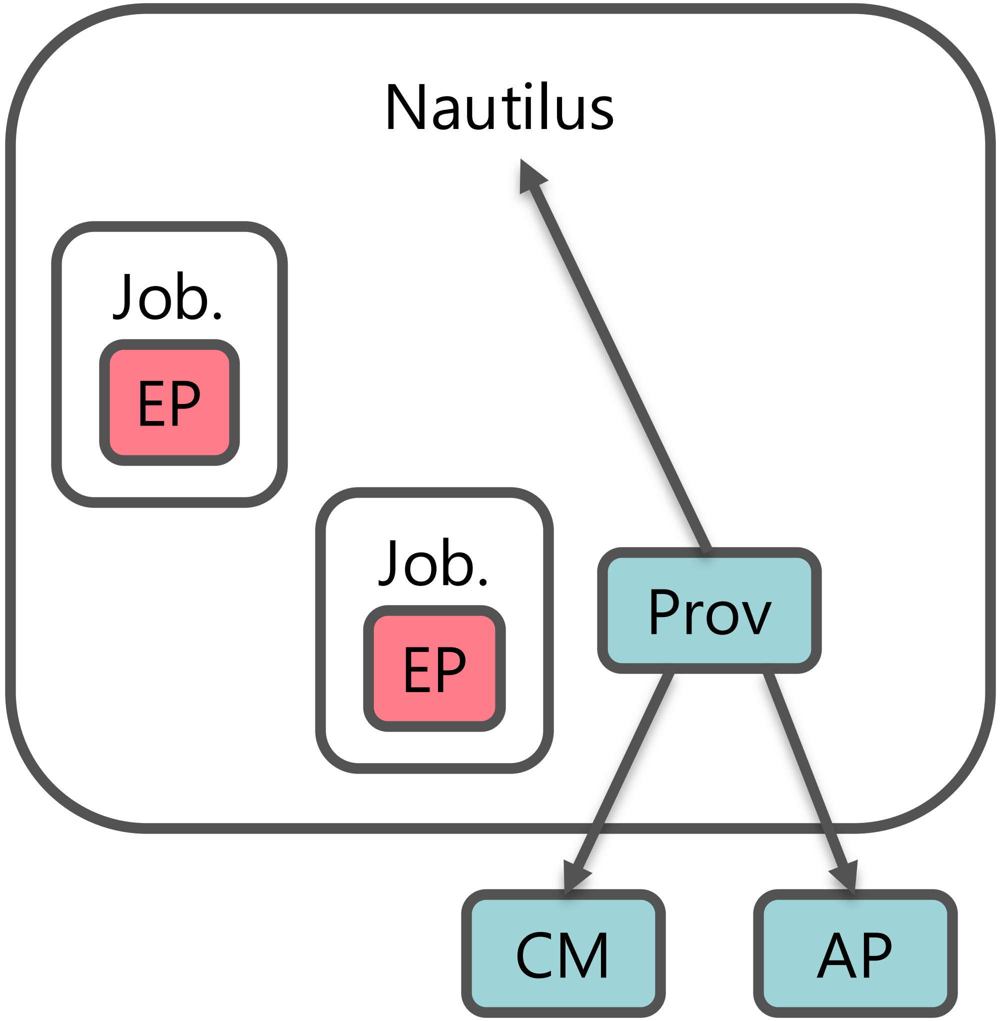

- The NRP has a *[provisioner component]()* that will create new K8S jobs containing an EP pod.
- The provisioner runs a periodic cycle where it (a) determines the current EP states, (b) determines the load, and (c) creates new jobs accordingly.
- When an EP is idle for a fixed period, it'll exit.
  - **Returns resources back to the cluster**.
- Provisioner needs to be configured with the EP image to use and the "needed resource" logic.

NRP: Scaling Up, Scaling Down

- Scaling down is natural:
  - When no job has matched for **X** minutes, the EP shuts off. All resources are cleaned up.
  - Analogous to a pilot / glidein-based system.
- Scaling up is complicated:
  - Provisioner must be configured to query for specific jobs.
  - Based on # of idle jobs, decides to launch new EPs.
  - **Problem**: provisioner query != negotiation. Relies on administrator to hand-write the expressions.
    - If administrator “gets it wrong”, then EP will idle and the resources will be wasted.

Comparisons: PATh Facility vs NRP

- The PATh Facility model is limited by deployment model: difficult to update the container image.
- The NRP model requires the administrator to write expressions matching jobs.
  - Quite difficult to get correct: near-impossible for GPU jobs.

What condor_q query do you write to count jobs if the job requirements are like this:

```
Requirements =
  ((Target.CUDADriverVersion >= 12.1) &&
   (Target.GPUs_GlobalMemoryMb > 45000) &&
   (Target.GPUs_GlobalMemoryMb < 60000)) &&
   …
```

E.g., NRP needs to query for all jobs that could utilize a host with 48GB of GPU memory but the job's GPU memory request is embedded in the Requirements expression.

Looking into the future: A HTCondor Operator

- The HTCSS team is working on its own Kubernetes operator, the “**glidein manager**”.
- Serves as a “CE”: an aggregation point for all EPs within a cluster.
- Purpose-built: aiming to tackle authorization models for the annex.
- Will provide an opportunity to combine the PATh Facility and the NRP models:
  - No penalties of deployment as in PATh Facility.
  - Can use offline ads / negotiatior, avoiding the expressions in the NRP model.
- Glidein Manager will serve as a CE, also managing the creation of the EP and any necessary credentials.

Matt Westphall

Lead developer for the “glidein manager”.

Questions?

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