Borg, Omega, and K8S

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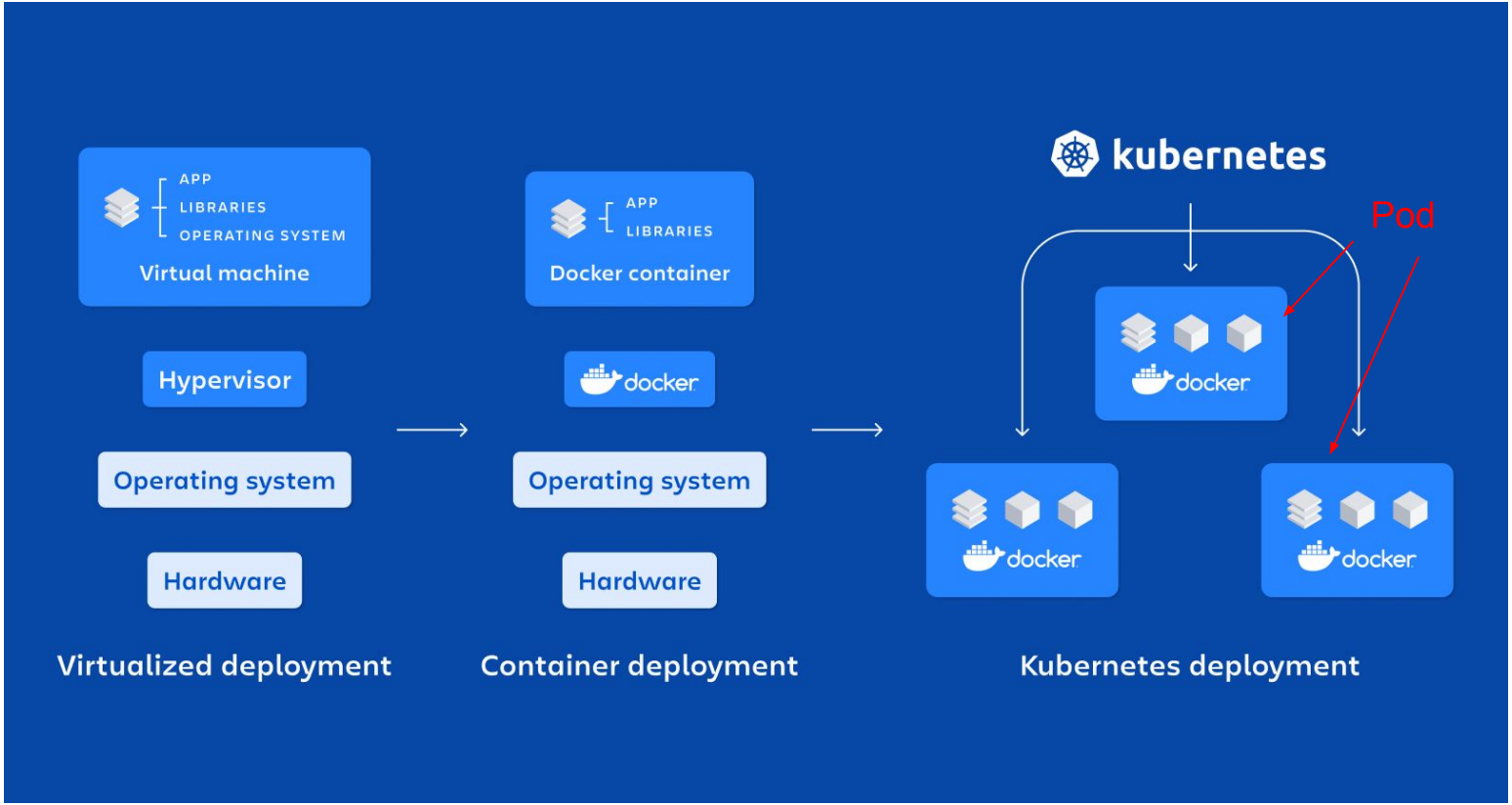
Containers, VMs, and Container Management Systems

VMs, Containers, and Container-Management Systems



Credit: https://www.atlassian.com/microservices/microservices-architecture/kubernetes-vs-docker#:~:text=Kubernetes%20vs.-,Docker,CRI%20(Container%20Runtime%20Interface).

Borg, Omega, and K8s

Borg, Omega, K8S

Borg

- Primary container management system within google
- Broad ecosystem of **heterogeneous, ad-hoc systems** built on top of Borg
- **Monolithic**, centralized master (Borgmaster) managing everything

Lots of complexity!

Manage complexity

Omega

- Redesign of Borg to improve engineering of Borg ecosystem
- **Wanted a more consistent, principled architecture**
- Borgmaster functionality broken into separate "**peer**" components
- State stored in a centralized Paxos-based **transaction oriented store** (**only centralized component**)
- Exposes state store directly to **trusted control-plane components**

Not suitable for a public cloud, (potentially) inconsistent designs

Kubernetes

- Open source!
- Core is comprised of a shared persistent store, with components watching for changes to relevant objects
- State is accessed **EXCLUSIVELY** through a domain-specific REST API to **support more diverse clients**
- **Focused on providing good experience to developers** writing applications to run in a cluster

Enforce system-wide invariants, policies, data transforms

Discussion Primer: Design Goals and Key Themes

- Use case & design goals:
  - Borg: **Internal-use** container management system
  - Omega: Borg but with better **software engineering practices**
  - Kubernetes: **Open source** container management software - emphasis on application developer experience
- Centralization vs Componentization (**Decoupling**)
  - Borg: Borgmaster is a **monolithic component** knowing semantics of **every** API operation
  - Omega: only has a centralized state store - all logic and semantics are pushed to store clients
    - Better scalability and consistency, less complexity
  - K8S: **componentized architecture** like Omega but enforces system-wide invariants, policies, dand data transformation by funneling all store accesses through a centralized API server

Discussion

“The container has become the sole runnable entity supported by the google infrastructure.”

Why pick containers as the “sole runnable entity”?

- Raise the level of abstraction in data centers from managing machines to managing applications
  - Abstracting away specific details of machines and OSes for application development
  - Enables infrastructure teams to manage/upgrade infra with minimal application impact
  - Improves application monitoring and introspection (telemetry data tied to applications)
- Container provide various benefits in developing and running applications
  - Isolation
  - Utilization improvement
  - Dependency minimization and portability (decoupling)
    - Easy development, debugging, deployment, introspection
  - Lower overhead than VMs
- Are there any drawbacks to this approach?

How did resource isolation provided by containers enable higher utilization of machines at google?

- Colocate batch jobs with latency-sensitive, user-facing jobs.
  - User-facing jobs reserve more resources than they need (to handle load spikes and fail-over)
  - Batch jobs can reclaim unused resources (when not needed by user-facing jobs)
- Why do we care about latency-sensitive jobs and batch jobs?
  - Latency-sensitive jobs pay the bills (e.g. search) - allocated for peak load (resources oversubscribed)
  - Batch jobs - not as time-sensitive (e.g. analytics)

What do you think are some goals, non-goals, and constraints in the design of Borg, Omega, K8s?

- Example goals, non-goals:
  - Scalability, Flexibility, Performance (e.g. utilization), Efficiency, Consistency, Application development velocity/agility, Composability
- Example constraints:
  - Internal use vs Open Source
- How did these influence design choices in Borg, Omega, and K8s? Is there anything you would do differently given the design requirements?

Why do we care about consistency (of interfaces, system components, etc.) and what are the benefits of uniform APIs?

- Easier to learn system (generally systems are simpler)
- Easier to write **generic tools** and have **consistent user experiences**
- Uniform API → Control accesses to components
  - e.g. enforce system-wide invariants, policies, data transforms
- More generally how can we achieve consistency in our systems?
  - **Uniform API**
  - **Decoupling** - separation of concerns between API components → higher-level services all share the same common basic building blocks
  - **Common design patterns**

Page 12 mentions that Kubernetes is being extended to enable users to add their own APIs dynamically, alongside the core kubernetes functionality.

- Trade-off between flexibility and consistency?
- Do you think this will create a large increase in complexity of systems?
- Recall that Borg had problems with a large collection of heterogeneous, ad-hoc systems…
- Recall that K8s is open source and is meant to support a diverse set of clients…
- Is this a good idea?

What is “control through choreography”? Why is it beneficial?

- Achieve a desired emergent behavior by **combining** the effects of **separate autonomous entities** that **collaborate**
  - Each entity has to manage its own (relatively) simple state space
  - Separation of concerns
- Centralized orchestration system (alternative design)
  - Easier to construct at first but becomes brittle and rigid over time, especially in the presence of unanticipated errors or state changes
  - Huge state space to consider, lots of complexity

What are some things to avoid? Why?

- Don’t make the container system manage port numbers
  - Assign unique **port** numbers (Borg) or **IP** addresses (K8s) to containers
- Don’t just number containers: give them labels (for grouping)
  - Indexing by **numbers** (Borg) vs **labels** (K8s)
  - Think about the scenarios where there are **lots of containers**
- Be careful with **ownership**
  - Tasks owned by jobs (Borg) vs separation of controllers and pods (K8s)
  - Think about debugging
- Don’t expose **raw** state (but we still need accesses to state)
  - **Monolithic** (Borg)
  - **Componentized**, state stored in centralized store, logic pushed into clients (Omega)
  - Centralized API server (K8s)

What are some open problems? Ideas?

- Application configuration
  - Commonly becomes the “catch-all” location for implementing things the container management system doesn’t do yet
  - (Solution?) want to maintain clear separation between computation and (configuration) data
- Dependency management
  - Services typically require other related services (e.g. monitoring, storage, CI/CD), how to automatically instantiate?

End!