Borg, Omega, and Kubernetes

Shane Cooke / 17400206 / Group K

The paper that I am reviewing today is titled “Borg, Omega, and Kubernetes”[1], and details Google’s journey to create efficient, robust, scalable and multi-feature container management systems. It was written by Brendan Burns, Brian Grant, David Oppenheimer, Eric Brewer and John Wilkes, who are all Google employees in the fields of software engineering, infrastructure management and cluster management. The paper was written in January of 2016, and details Google’s discoveries, innovations and downfalls over a 10 year period in the field of container management systems. This paper reveals both the successes and failures of this process and describes each step of this journey in great detail and honesty.

The main features of this paper are Borg, Omega and Kubernetes, which are three different container management systems created and procured by Google. Borg was Google’s first unified container-management system, and was built to manage both long-running services and batch jobs, which had previously been managed by multiple different system’s within Google. Borg remains the primary system within Google because of its scale, breadth of features and extreme robustness. However even though Borg was successful in many areas, Google where unhappy with its inconsistent and unprincipled architecture. Borg was created layer-by-layer as Google continually added more applications to run on top of Borg which resulted in users of Borg having to configure and interact with multiple different configuration languages and processes. Google’s second container management system called Omega was created to solve this problem. Omega used much of the same processes as Borg, however it was built from the ground up to have a more consistent and principled architecture. Omega was never deployed by Google, however it certainly was not a failed project, as many of Omega’s innovations such as multiple schedulers have since been folded into Borg. The third container management system created at Google is called Kubernetes. Google had developed a growing business selling public-cloud infrastructure which led them to want to develop an open-source system. Kubernetes’ goal was to make it easy to deploy and manage complex distributed systems and unlike Borg and Omega, Kubernetes is accessed through a domain-specific REST API and has an open-source GitHub repository.

The authors believe containers and container management systems to be the solution to a vast array of problems in the computing world. The resource isolation provided by containers enabled Google to “drive utilisation significantly higher than industry norms” and containers also provided the resource-management tools to make this possible. Containerization also transformed the data centre from being machine-oriented to being application-oriented, and provided abstraction of many of the details of machines and operating systems away from the application developer and the deployment architecture. Because well-designed containers and container images are scoped to a single application, managing containers means managing applications rather than machines. This shift of management APIs from machine-oriented to application oriented dramatically improved application deployment and introspection in Google. The Borg, Omega and Kubernetes systems vary quite widely in features, usage and configuration, however each aims to achieve the same goals of isolation, abstraction, resource-management and easy app deployment.

Containers and container management systems are repeatedly hailed in this paper as a massive reason for Google’s success today with statements such as “the resource isolation has enabled Google to drive utilization significantly higher than industry norms” and “the benefits of containerization go beyond enabling higher levels of utilization, it transforms the data center”. Borg is said to “improve deployment and speed up development by reducing inconsistencies and friction” and about Kubernetes it is said “the isolation and dependency minimization provided by containers have proved quite effective at Google”. Google’s evaluation process in this paper is largely based on the trial and error nature of their container systems, and a list of “Things to Avoid” is provided for the design of these distributed system’s such as “Don’t make the container manage port numbers” and “Don’t expose raw state”. The evaluation of each system is overwhelmingly positive in this paper, however very little information is given regarding performance and user data. Borg is an internal system only used within Google and Omega was never deployed, so this is unsurprising. However Kubernetes is open-source and so, there is a vast array of both performance and user data available. A 2020 article by K. Casey[2], states that 78% of firms included in a CNCF report used Kubernetes in some form and that it was the 4th fastest growing open-source project on all of GitHub. A CNCF report from 2019[3], reveals that 2.7 million developers where using Kubernetes in 2019 and that 9 out of 10 developers who use containers are aware of it. A 2020 report by B. Doerrfeld[4] revealed that Kubernetes use grew 48% between the years of 2018 and 2019 which is a very healthy growth rate. The extremely positive evaluation of Borg, Omega and Kubernetes in this paper is reinforced by the performance and user data available about Kubernetes online and proves that Google both have and are reaping huge benefits from their use of container technology.

References

[1] Grant, B., Oppenheimer, D., Brewer, E., Wilkes, J., **Borg, Omega and Kubernetes**,

https://static.googleusercontent.com/media/research.google.com/en//pubs/archive/44843.pdf

[2] Casey, K., **Kubernetes by the numbers in 2020: 12 stats to see**,

https://enterprisersproject.com/article/2020/6/kubernetes-statistics-2020

[3] Lacozza, S., Korakitis, K., Veritsis, A., **The State Of Cloud Native Deployment**,

https://www.cncf.io/wp-content/uploads/2020/08/CNCF-The-State-of-Cloud-Native-Development_Q419.pdf

[4] Doerrfeld, B., **Best of 2020: VMware Releases State of Kubernetes 2020 Report**,

https://containerjournal.com/topics/container-ecosystems/vmware-releases-state-of-kubernetes-2020-report/