# Bunk8s: Enabling Easy Integration Testing of Microservices in Kubernetes

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Abstract-Microservice architecture is the common choice for cloud applications these days since each individual microservice can be independently modified, replaced, and scaled. However, the complexity of microservice applications requires automated testing with a focus on the interactions between the services. While this is achievable with end-to-end tests, they are errorprone, brittle, expensive to write, time-consuming to run, and require the entire application to be deployed. Integration tests are an alternative to end-to-end tests since they have a smaller test scope and require the deployment of a significantly fewer number of services. The de-facto standard for deploying microservice applications in the cloud is containers with Kubernetes being the most widely used container orchestration platform. To support the integration testing of microservices in Kubernetes, several tools such as Octopus, Istio, and Jenkins exist. However, each of these tools either lack crucial functionality or lead to a substantial increase in the complexity and growth of the tool landscape when introduced into a project. To this end, we present Bunk8s, a tool for integration testing of microservice applications in Kubernetes that overcomes the limitations of these existing tools. Bunk8s is independent of the test framework used for writing integration tests, independent of the used CI/CD infrastructure, and supports test result publishing. A video demonstrating the functioning of our tool is available from https://www.youtube.com/watch?v=e8wbS25O4Bo.

Index Terms—DevOps, Integration Testing, Kubernetes, Microservices

## I. INTRODUCTION

Microservices-based applications are typically composed of independently deployable components that can be directly translated into services and automatically scaled on-demand. Components are independently replaceable and upgradable units of software [1], consisting of several modules [2]. Linux containers, due to their portability, isolation, and high availability, have become the de-facto standard for developing, testing, and deploying such applications in cloud environments [3]. This is because containers enable users to package their application and its custom software dependencies as a single unit into easy-to-deploy images. Moreover, containers are a natural fit for microservices-based applications in the cloud due to their smooth integration with container orchestration platforms [4] for efficient resource management. Recent trends [5] show that nearly 90% of all deployed containers are orchestrated, with Kubernetes (k8s) [6] being the most utilized container orchestration platform [7].

Developers can deploy k8s on-premise or can utilize the services offered by most commercial cloud providers such as Microsoft (Azure Kubernetes Service) [8]. If a microservicebased application is deployed to a k8s cluster, it may rely on backend services that run outside the k8s cluster. For instance, services that provide storage or networking functionalities. For commercial cloud providers, these services are self-managed, with only the service's live API available for the developer to access. As a result, testing the interactions of modules from a microservice application with the modules from the backend service requires the entire backend service to be deployed. It cannot be done in isolation with only specific modules of the backend service. Therefore, testing the interactions of a microservice application with backend services can only be accomplished by running end-to-end tests or broad integration tests. Note that, integration tests can be classified into narrow and broad depending on their granularity (§II).

End-to-end tests are brittle, expensive to write, timeconsuming to execute, and require the deployment of the entire application [9]. Broad integration testing of microservices in k8s can be done in two ways, i.e., from inside or outside the cluster. Running broad integration tests for microservices from outside the k8s cluster has several drawbacks, making them as inefficient as end-to-end tests. For example, the lack of public interfaces in the services which allow them to be accessed from outside the k8s cluster. As a result, the standard way of broad integration testing of microservices is from inside the k8s cluster. For the integration testing of microservices from inside the k8s cluster, several tools such as Octopus [10], Istio [11], and Jenkins [12] exist. However, the existing tools lack crucial functionalities or are dependent on particular infrastructure for the execution of these tests. To this end, we present Bunk8s that overcomes the limitations of these existing tools.

Towards easy integration testing in Kubernetes, our key contributions are:

- We implement and present *Bunk8s*<sup>1</sup>, a tool for broad integration testing of microservices in Kubernetes.
- *Bunk8s* is independent of the test framework used for writing integration tests, independent of the used CI/CD infrastructure, and supports publishing of test results.

<sup>1</sup>https://github.com/Teiktos/bunk8s

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Fig. 1: Narrow and Broad integration testing.

Thus, making the inclusion of *Bunk8s* in a project relatively easy.

• We demonstrate the functioning of *Bunk8s* by running broad integration tests for a real-world microservice application on a commercial cloud provider, i.e., Azure.

The rest of the paper is structured as follows. §II provides a background on integration testing. In §III, the system design of *Bunk8s* and its workflow for integration testing of microservices are described. In §IV, we demonstrate the functioning of *Bunk8s* for the integration testing of a real-world microservice application. §V motivates the need for *Bunk8s* and presents a comparison with other tools for integration testing of microservices. Finally, §VI concludes the paper and presents an outlook.

# II. BACKGROUND

Integration tests are generally used to verify the interactions between the layers of integration code and the external microservices to which they are integrating [2]. They can be further categorized by their granularity, into narrow and broad integration tests. Narrow integration tests refer to testing only the modules of microservices that communicate with each other. Therefore, they only require instantiating the modules under test [13]. Microservice applications that run in commercial cloud offerings of k8s may integrate with services that run outside of k8s, e.g., Azure Cosmos DB, Azure Service Bus. Such services only provide developers with their live versions and it is not possible to instantiate only modules of these services that can integrate with the components of the microservice application. As a result, testing the interaction of microservices and services external to Kubernetes is not possible with narrow integration tests. On the other hand, broad integration tests refer to testing code paths through several services and all of their modules. Moreover, broad integration tests can be of varying granularity, depending on the scope of the subsystem under test [2]. They require live versions of the components under test, a substantial test environment and network access [13]. The difference in the code paths used for writing narrow and broad integration tests is shown in Figure 1.

## III. BUNK8s

In this section, we first describe our design goals for the development of *Bunk8s*. Following this, we present its system



Fig. 2: Component diagram of Bunk8s.

design. Finally, we describe in detail, the workflow of *Bunk8s* for the broad integration testing of microservices in k8s.

# A. Design Goals

To facilitate the ease-of-use for utilizing *Bunk8s* in a project and to overcome the limitations of the current tools for the integration testing of microservices in k8s (§V), we chose the following design goals:

- Independence of the testing framework used for writing and generating tests.
- Independent of the specific CI/CD tools used within a project.
- Compatible with different container runtimes such as containerd [14] and CRI-O [15].
- Portable across the different Kubernetes offerings by the commercial cloud providers such as AKS [8], GKE [16].
- Support for publishing of test results.

#### B. System Design

Bunk8s allows deploying test runner containers in test runner pods to a testing namespace. In this namespace, the microservices under test are deployed. Note that, test runner containers are written by developers and contain the integration tests for the microservice application. Following this, the tests are executed by the test runner containers. Setting up of the cloud infrastructure and the deployment of the microservices under test is not a functionality of Bunk8s and should be done with tools such as Helm [17] or Terraform [18]. The different components of Bunk8s are shown in Figure 2. It consists of two components, i.e., ① the Launcher and ② the Coordinator. The Launcher runs in the CI/CD pipeline while the Coordinator runs in the k8s cluster.

1) The Launcher: The Launcher runs outside of k8s as part of the continuous integration (CI) process in a pipeline. After the container images of the microservices under test are built and pushed to a container registry by the pipeline, the *Bunk8s* launcher is started, which in turn starts the testing process. The launcher takes a YAML configuration file as input, an example of which is shown in Listing 1. The configuration file provides the relevant information that is required by the launcher for connecting to the coordinator (§III-B2), i.e., its IP address and port number. The developers can also provide a TLS certificate file for an authorized connection that is placed in the container image of the launcher. The configuration file also includes information required by the coordinator for running



Listing 1: Example configuration file taken as input by the *Bunk8s* launcher.

the integration tests. This includes the names of the test runner images, the namespace to which the test runner pods should be deployed, the name of the test runner pods, and a test timeout value. Note that, the list testRunnerPods allows defining multiple test runner pods which can be deployed in different namespaces, while the list containers allows defining multiple test runner containers per pod. The launcher connects to the coordinator via HTTP and sends the configuration data. After the testing has finished, the coordinator responds to the launcher. Following this, the launcher calls the *kube-apiserver* and extracts the test results from the test runner containers via HTTP, and stores them on the pipeline runner. Pipeline runner is an agent that executes the CI/CD workflow. After the extraction, the test results can be published with the pipeline's default test result publishing functionality such as GitLab artifacts [19]. The launcher is designed to run in a container which makes it platform-independent and easily adaptable to other container runtimes.

2) The Coordinator: The Bunk8s Coordinator handles the deployment of the test runner containers and watches their state until they have finished. It consists of two subcomponents. First, an RPC server for communication and synchronization between the launcher and the coordinator. Second, a k8s clientset that connects to the kube-apiserver via HTTP, sends a request to create the test runner pods, and watches their state. The coordinator's RPC server is exposed to the launcher via an Ingress. On test completion, the coordinator sends a response to the Launcher, containing the information that is required to extract the test results from the test runner containers. The test runner container image that is deployed in a pod by the Bunk8s coordinator must be built and pushed to a container registry from which k8s can pull container images. Since the integration tests are executed inside a container that is separate from the other components of Bunk8s, the developers can use any test framework or programming language to write their tests.

#### C. Integration testing with Bunk8s

To install *Bunk8s* in a k8s cluster, the launcher and coordinator (§III-B) images must be built using Dockerfiles. The launcher image must be uploaded to a container registry from where it can be pulled by the pipeline runners, while the coordinator image must be uploaded to a registry to which



Fig. 3: Workflow of Integration testing with Bunk8s.

the k8s cluster has access. For a quick setup of the *Bunk8s* coordinator, we provide a pre-configured Helm chart in our repository (§I). Note that, the coordinator can be deployed in any k8s namespace without affecting its functionality. However, it is recommended that the coordinator is deployed in a namespace of its own. The project admin is responsible for creating the role-based access control rules (RBAC) for the coordinator pod in its namespace. The detailed workflow of the testing process with *Bunk8s* is shown in Figure 3.

At the beginning  $\mathbf{1}$ , the *Bunk*8s launcher container is started by using a launch script. The launcher takes a YAML configuration file as input (§III-B) which is mounted into the container at startup. The YAML parser parses the configuration file, checks if it is valid 2, and creates a Go struct from the configuration data 3. Following this, the gRPC client is created that receives the test run configuration created in the previous step 4. The gRPC client calls the DeployTestRunner RPC method registered in the gRPC server that invokes several functions defined in the kubeclient package 5. For brevity, those function names have been omitted from Figure 3. As part of the RPC method in 5, the kubeclient does several HTTP requests to the kube-apiserver. First, it does a GET request for each namespace provided in the configuration data 6. After it receives a response, it checks if the given namespaces already exist or not. If not, the test run is terminated and the coordinator sends an error code as a gRPC reply to the launcher. Second, it does a GET request for each pod from the configuration data **7**. On receipt of the response, it checks whether the pods already exist within the namespace that they should be scheduled in. If the pods do not exist, the kubeclient creates k8s API pod objects. Third, it does a POST request for each pod object created in the previous step 8. After this, the test runner pods are created by the kube-apiserver **9**. Finally, the kubeclient creates a watcher for each test runner pod. After all the tests have finished, the DeployTestRunner RPC method ends 10. Following this, the gRPC server sends the server response to the gRPC client which is written to the logs of the Bunk8s launcher container **11**. The server reply is stored as a JSON file by the launch script (12) and then read by the data extraction script (13). After this, the data extraction script executes kubectl which



Fig. 4: Room Tracking Application Microservices.

does an HTTP POST request to the kube-apiserver to copy the test results from the test runner pods to the pipeline runner **14**. The test results are extracted by the kube-apiserver from the sidecar containers inside the test runner pods **15**. Following this, the test results are stored on the pipeline runner **16**. Finally, the data extraction script does an HTTP DELETE request to the kube-apiserver (**17**) to delete the test runner pods (**18**). The results of the integration tests can now be published using the CI pipeline's publishing mechanisms.

# IV. CASE STUDY: ROOM TRACKING SYSTEM

In this section, we demonstrate the usage of *Bunk8s* for the broad integration testing of a real-world microservice application.

## A. Experimental Setup

To demonstrate the functioning of *Bunk8s*, we create a Kubernetes cluster using the Azure Kubernetes Service (AKS) [8]. We use GitLab as the DevOps platform since it provides remote Git repositories and CI/CD pipelines [20]. As the registry for containers, we use the Azure Container Registry [21]. The chosen application and *Bunk8s* are deployed to the AKS by utilizing the pipeline functionality present in GitLab. Although we use AKS for our experiments, *Bunk8s* is compatible with commercial k8s offerings of all cloud providers.

#### B. Application Design

The application we use is a room tracking system. A user can hold a card up to a badge reader inside a room and that room will be marked as occupied by the application. Users can also access a dashboard via a browser that provides an overview of the room utilization. Furthermore, when a user enters a room, it is announced on a shout website that is separate from the dashboard.

Figure 4 gives an overview of the different microservices present in the room tracking system. It consists of two frontend services, i.e., *Dashboard* and *Shout*, three backend services, i.e., *Device*, *Account*, and *Room*, and two infrastructure services, i.e., *RabbitMQ* and *MongoDB*. The frontend services *Dashboard* and *Shout* provide the dashboard and shout websites. *RabbitMQ* provides message queues for the communication between the *Device*, *Dashboard*, *Shout* and

Listing 2: Test result logs after successful completion of the									
12	db	ok	show	case 0.435s					
11	do	PAS	s						
10	dlo		PASS:	TestMongoDBRoomAllocationEntry (0.09s)					
9	dlo	===	=== RUN TestMongoDBRoomAllocationEntry						
8	dp		PASS:	TestRoomServiceRoomEventResponse/Queue Shout (0.00s)					
7	dp		PASS:	TestRoomServiceRoomEventResponse/Queue_Dashboard (0.00s)					
6	dlo		PASS:	TestRoomServiceRoomEventResponse (0.07s)					
5	ę	===	RUN	TestRoomServiceRoomEventResponse/Queue_Shout					
4	do	===	RUN	TestRoomServiceRoomEventResponse/Queue_Dashboard					
3	do	===	RUN	TestRoomServiceRoomEventResponse					
2	do		PASS:	TestDeviceServiceReceiveDeviceEvent (0.27s)					
1	db		RUN	TestDeviceServiceReceiveDeviceEvent					

Listing 2: Test result logs after successful completion of the broad integration tests with *Bunk8s*.

1	[]									
2	=== RUN TestMongoDBRoomAllocationEntry									
3	main_test.go:152: Failed to create MongoDB client: Failed to ping MongoDB: server selection error: context deadline exceeded, current topology: { Type: Unknown, Servers: [{ Adir: mongodb://mongo. bunk8s-fe.svc.cluster.local, Type: Unknown, Last error: connection () error occured during connection handshake: dial top mongodb ://mongo.bunk8s-fe.svc.cluster.local: connect: connection refused									
4	FAIL: TestMongoDRRoomAllocationEntry (10 00s)									
5	FATI.									
6	ok showcase 10.101s									

Listing 3: Test result logs after successful completion of the broad integration tests with *Bunk8s*.

the Room service. When a user enters a room, a badge reader device sends a badge reader event to the Device service. Following this, the Device service creates a device event containing the card and room numbers. The device event is then sent to the Room service via the message queue. The Room service updates the room allocation in MongoDB and creates a room event that describes which user entered or left the room and forwards it to the Dashboard and Shout services via the two different message queues. After receiving the room event, the Dashboard service updates a counter that tracks the number of users that have checked into a room. On the other hand, the Shout service requests the name of the user from the room event from the Account service. The Account service provides the functionality for creating, modifying, and listing the user accounts that are stored in the MongoDB service. Note that, AMQP [22] is a message protocol for transferring messages, while the wire protocol is the default communication protocol used by MongoDB [23].

# C. Broad Integration Testing Results

Broad integration tests cover multiple code paths through several microservices and all of their components (§II). As a result, multiple services of the room tracking application will be under test (§IV-B). Since *Bunk8s* enables testing of backend services without requiring the reconfiguration of ingresses in k8s, as well as the testing of backend services that do not provide an HTTP or HTTPS interface, the services *Dashboard*, *Shout*, and *Account* are not tested and omitted from deployment. To this end, the microservices under test are *Device*, *Room*, *RabbitMQ*, and *MongoDB*.

For writing the integration tests, we use Go and its default testing package. We generate a badge reader event which is sent to the *Device* service. Following this, the contents of the room events created by the *Room* service are checked for validity. Finally, we check the validity of the room allocated in the *MongoDB* database. As described in §III-C, the test results

Supported Features	Bunk8s [This Work]	Octopus [10]	Istio [11]	Jenkins [12]					
Broad integration testing	Û	ŵ							
Narrow integration testing	•	•	ŵ	Û					
Test framework independent	Û	ŵ		Û					
CI/CD Infrastructure independent	Ú	ŵ							
Test result publishing	Ô	<b>••</b>	Ô	Ô					

TABLE I: Comparison of the different features supported by Bunk8s with the other available tools for integration testing. Supported. PNo support.

are extracted and stored in artifact store provided by GitLab. Listing 2 shows the logs of the test results after all broad integration tests have completed successfully. *Bunk8s* also extracts test results if a test fails. For instance, Listing 3 shows logs of the test TestMongoDBRoomAllocationEntry when no connection to the *MongoDB* service could be established. As a result, the test result publishing supported by *Bunk8s* allows developers to easily analyse and debug their applications.

## V. WHY BUNK8S?

To support the integration testing of microservices inside k8s several tools exist. These include Octopus [10], Istio [11], and Jenkins [12]. Octopus allows developers to define integration tests with custom resource definitions [24]. For each test, Octopus deploys a pod to k8s. Furthermore, it supports re-running tests to prevent flaky test results. The Istio testing framework allows developers to test microservice applications that use the Istio service mesh to handle the communication between microservices. Developers can also use Jenkins to run integration tests inside k8s by using the different Kubernetes plugins [25]. A comparison of the different features supported by *Bunk8s* with the other tools is shown in Table I.

Both Istio and Jenkins only support narrow integration testing (§II). For Istio, this is possible due to the presence of sidecar containers for pods. On the other hand, both Octopus and Bunk8s support broad integration testing which enable the testing of interactions between the application microservices and the backend services. For all the tools shown in Table I, the developers can use any programming language and test framework for writing integration tests except Istio. Since Istio is an expansion of the Go testing package it only supports writing integration tests in Go. Moreover, Istio is dependent on the usage of Prow [26] as the CI/CD system for running the integration tests [27]. Similarly, using Jenkins would require it's introduction into a project and migration of at least parts of the CI/CD pipeline to Jenkins if not already in use. In contrast, both Bunk8s and Octopus can be used with any CI/CD tool that supports Docker containers. A major drawback of using Octopus is that after a test is finished it only reports whether a test failed or was successful and does not extract the test logs from the containers. This prevents an in-depth analysis of test failures [28]. Moreover, Octopus is not open-source and charges for its services. On the other hand, Bunk8s is completely open-source and supports publishing of test results since they are extracted from the test runner pod and are stored on the pipeline runner (§III-B). Following this, the supported pipeline mechanisms for test result publishing can be utilized.

As a result, the different features supported by *Bunk8s* make it easier for it to be integrated into an existing projects pipeline.

# VI. CONCLUSION & FUTURE WORK

In this paper, we implemented and presented *Bunk8s*, a tool for broad integration testing of microservices in Kubernetes. *Bunk8s* is independent of the test framework used for writing or generating tests, independent of the infrastructure or platform on which Kubernetes runs, and supports test result publishing. *Bunk8s* is well suited for developers planning to write a new test suite as well as for developers who wish to revise and improve the already existing test suite of a microservice application. In the future, we plan to extend *Bunk8s* to support mocking of services. Furthermore, we plan to eaded support for narrow integration testing in *Bunk8s* to enable testing of multi-container pods. Support for FaaS based CI/CD workloads is another future direction [29].

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