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DevOps

A Software Architect's Perspective

Len Bass

Ingo Weber

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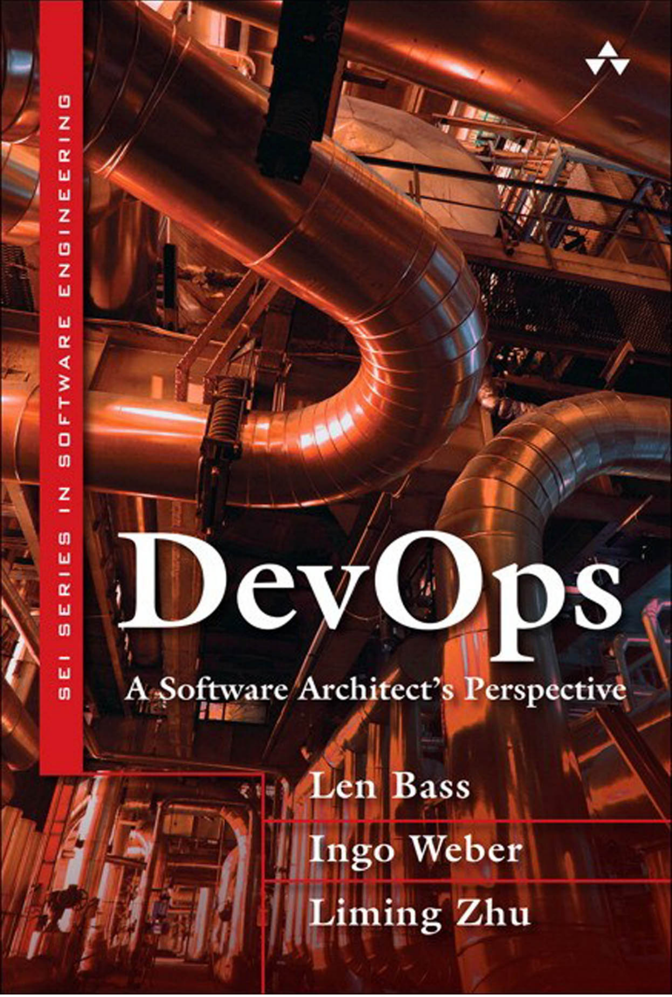

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Preface

We have been investigating problems in operations for several years and have, naturally, been tracking the DevOps movement. It is moving up the Gartner Hype Curve and has a solid business reason for existing. We were able to find treatments from the IT manager's perspective (e.g., the novel *The Phoenix Project: A Novel about IT, DevOps, and Helping Your Business Win*) and from the project manager's perspective (e.g., *Continuous Delivery: Reliable Software Releases Through Build, Test, and Deployment Automation*). In addition, there is a raft of material about cultural change and what it means to tear down barriers between organizational units.

What frustrated us is that there is very little material from the software architect's perspective. Treating operations personnel as first-class stakeholders and listening to their requirements is certainly important. Using tools to support operations and project management is also important. Yet, we had the strong feeling that there was more to it than stakeholder management and the use of tools.

Indeed there is, and that is the gap that this book intends to fill. DevOps presents a fascinating interplay between design, process, tooling, and organizational structure. We try to answer two primary questions: What technical decisions do I, as a software architect, have to make to achieve the DevOps goals? What impact do the other actors in the DevOps space have on me?

The answers are that achieving DevOps goals can involve fundamental changes in the architecture of your systems and in the roles and responsibilities required to get your systems into production and support them once they are there.

Just as software architects must understand the business context and goals for the systems they design and construct, understanding DevOps requires understanding organizational and business contexts, as well as technical and operational contexts. We explore all of these.

The primary audience for this book is practicing software architects who have been or expect to be asked, "Should this project or organization adopt DevOps practices?" Instead of being asked, the architect may be told. As with all books, we expect additional categories of readers. Students who are interested in learning more about the practice of software architecture should find interesting material here. Researchers who wish to investigate DevOps topics can find important background material. Our primary focus, however, is on practicing architects.

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Previewing the Book

We begin the book by discussing the background for DevOps. Part One begins by delving into the goals of DevOps and the problems it is intended to solve. We touch on organizational and cultural issues, as well as the relationship of DevOps practices to agile methodologies.

In Chapter 2, we explore the cloud. DevOps practices have grown in tandem with the growth of the cloud as a platform. The two, in theory, are separable, but in practice virtualization and the cloud are important enablers for DevOps practices.

In our final background chapter, Chapter 3, we explore operations through the prism of the Information Technology Infrastructure Library (ITIL). ITIL is a system of organization of the most important functions of an operations group. Not all of operations are included in DevOps practices but understanding something of the responsibilities of an operations group provides important context, especially when it comes to understanding roles and responsibilities.

Part Two describes the deployment pipeline. We begin this part by exploring the microservice architectural style in Chapter 4. It is not mandatory that systems be architected in this style in order to apply DevOps practices but the microservice architectural style is designed to solve many of the problems that motivated DevOps.

In Chapter 5, we hurry through the building and testing processes and tool chains. It is important to understand these but they are not our focus. We touch on the different environments used to get a system into production and the different sorts of tests run on these environments. Since many of the tools used in DevOps are used in the building and testing processes, we provide context for understanding these tools and how to control them.

We conclude Part Two by discussing deployment. One of the goals of DevOps is to speed up deployments. A technique used to achieve this goal is to allow each development team to independently deploy their code when it is ready. Independent deployment introduces many issues of consistency. We discuss different deployment models, managing distinct versions of a system that are simultaneously in production, rolling back in the case of errors, and other topics having to do with actually placing your system in production.

Part Two presents a functional perspective on deployment practices. Yet, just as with any other system, it is frequently the quality perspectives that control the design and the acceptance of the system. In Part Three, we focus on crosscutting concerns. This begins with our discussion of monitoring and live testing in Chapter 7. Modern software testing practices do not end when a system is placed into production. First, systems are monitored extensively to detect problems, and secondly, testing continues in a variety of forms after a system has been placed into production.

Another crosscutting concern is security, which we cover in Chapter 8. We present the different types of security controls that exist in an environment, spanning those that are organization wide and those that are specific system wide. We discuss the different roles associated with achieving security and how these roles are evaluated in the case of a security audit.

Security is not the only quality of interest, and in Chapter 9 we discuss other qualities that are relevant to the practices associated with DevOps. We cover topics such as performance, reliability, and modifiability of the deployment pipeline.

Finally, in Part Three we discuss business considerations in Chapter 10. Practices as broad as DevOps cannot be adopted without buy-in from management. A business plan is a typical means of acquiring this buy-in; thus, we present the elements of a business plan for DevOps adoption and discuss how the argument, rollout, and measurement should proceed.

In Part Four we present three case studies. Organizations that have implemented DevOps practices tell us some of their tricks. Chapter 11 discusses how to maintain two datacenters for the purpose of business continuity; Chapter 12 presents the specifics of a continuous deployment pipeline; and Chapter 13 describes how one organization is migrating to a microservice architecture.

We close by speculating about the future in Part Five. Chapter 14 describes our research and how it is based on viewing operations as a series of processes, and Chapter 15 gives our prediction for how the next three to five years are going to evolve in terms of DevOps.

Acknowledgments

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Addison-Wesley did their usual professional and efficient job in the production process, and this book has benefited from their expertise.

Finally, we would like to thank NICTA and NICTA management. NICTA is funded by the Australian government through the Department of Communications and the Australian Research Council through the ICT Centre of Excellence Program. Without their generous support, this book would not have been written.

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Legend

We use four distinct legends for the figures. We have an architectural notation that identifies the key architectural concepts that we use; we use Business Process Model and Notation (BPMN) to describe some processes, Porter's Value Notation to describe a few others, and UML sequence diagrams for interleaving sequences of activities. We do not show the UML sequence diagram notation here but the notation that we use from these other sources is:

Architecture

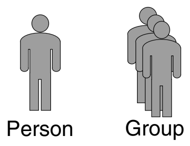

FIGURE P.1 People, both individual and groups

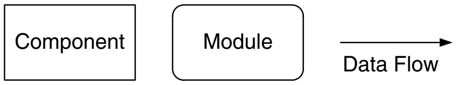

FIGURE P.2 Components (runtime entities), modules (code-time collections of entities), and data flow

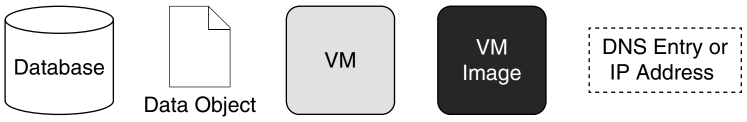

FIGURE P.3 Specialized entities

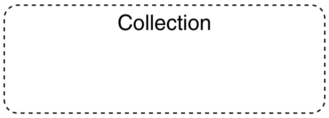

FIGURE P.4 Collections of entities

BPMN

We use Business Process Model and Notation (BPMN) for describing events and activities [OMG 11].

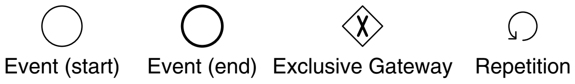

FIGURE P.5 Event indications

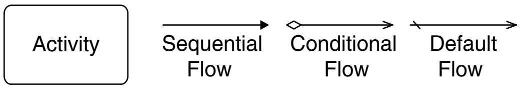

FIGURE P.6 Activities and sequences of activities

Porter's Value Chain

This notation is used to describe processes (which, in turn, have activities modelled in BPMN).

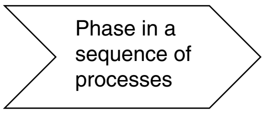

FIGURE P.7 Entry in a value chain

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4

Overall Architecture

A distributed system is one in which the failure of a computer you didn't even know existed can render you own computer unusable.
—Leslie Lamport

In this chapter we begin to see the structural implications of the DevOps practices. These practices have implications with respect to both the overall structure of the system and techniques that should be used in the system's elements. DevOps achieves its goals partially by replacing explicit coordination with implicit and often less coordination, and we will see how the architecture of the system being developed acts as the implicit coordination mechanism. We begin by discussing whether DevOps practices necessarily imply architectural change.

4.1 Do DevOps Practices Require Architectural Change?

You may have a large investment in your current systems and your current architecture. If you must re-architect your systems in order to take advantage of DevOps, a legitimate question is "Is it worth it?" In this section we see that some DevOps practices are independent of architecture, whereas in order to get the full benefit of others, architectural refactoring may be necessary.

Recall from Chapter 1 that there are five categories of DevOps practices.

1. Treat Ops as first-class citizens from the point of view of requirements. Adding requirements to a system from Ops may require some architectural modification. In particular, the Ops requirements are likely to be in the area of logging, monitoring, and information to support incident handling. These requirements will be like other requirements for modifications to a

system: possibly requiring some minor modifications to the architecture but, typically, not drastic modifications.

2. Make Dev more responsible for relevant incident handling. By itself, this change is just a process change and should require no architectural modifications. However, just as with the previous category, once Dev becomes aware of the requirements for incident handling, some architectural modifications may result.
3. Enforce deployment process used by all, including Dev and Ops personnel. In general, when a process becomes enforced, some individuals may be required to change their normal operating procedures and, possibly, the structure of the systems on which they work. One point where a deployment process could be enforced is in the initiation phase of each system. Each system, when it is initialized, verifies its pedigree. That is, it arrived at execution through a series of steps, each of which can be checked to have occurred. Furthermore, the systems on which it depends (e.g., operating systems or middleware) also have verifiable pedigrees.
4. Use continuous deployment. Continuous deployment is the practice that leads to the most far-reaching architectural modifications. On the one hand, an organization can introduce continuous deployment practices with no major architectural changes. See, for example, our case study in Chapter 12. On the other hand, organizations that have adopted continuous deployment practices frequently begin moving to a microservice-based architecture. See, for example, our case study in Chapter 13. We explore the reasons for the adoption of a microservice architecture in the remainder of this chapter
5. Develop infrastructure code with the same set of practices as application code. These practices will not affect the application code but may affect the architecture of the infrastructure code.

4.2 Overall Architecture Structure

Before delving into the details of the overall structure, let us clarify how we use certain terminology. The terms *module* and *component* are frequently overloaded and used in different fashions in different writings. For us, a module is a code unit with coherent functionality. A component is an executable unit. A compiler or interpreter turns modules into binaries, and a builder turns the binaries into components. The development team thus directly develops modules. Components are results of the modules developed by development teams, and so it is possible to speak of a team developing a component, but it should be clear that the development of a component is an indirect activity of a development team.

As we described in Chapter 1, development teams using DevOps processes are usually small and should have limited inter-team coordination. Small teams imply that each team has a limited scope in terms of the components they develop. When a team deploys a component, it cannot go into production unless the component is compatible with other components with which it interacts. This compatibility can be ensured explicitly through multi-team coordination, or it can be ensured implicitly through the definition of the architecture.

An organization can introduce continuous deployment without major architectural modifications. For example, the case study in Chapter 12 is fundamentally architecture-agnostic. Dramatically reducing the time required to place a component into production, however, requires architectural support:

- Deploying without the necessity of explicit coordination with other teams reduces the time required to place a component into production.
- Allowing for different versions of the same service to be simultaneously in production leads to different team members deploying without coordination with other members of their team.
- Rolling back a deployment in the event of errors allows for various forms of live testing.

Microservice architecture is an architectural style that satisfies these requirements. This style is used in practice by organizations that have adopted or inspired many DevOps practices. Although project requirements may cause deviations to this style, it remains a good general basis for projects that are adopting DevOps practices.

A microservice architecture consists of a collection of services where each service provides a small amount of functionality and the total functionality of the system is derived from composing multiple services. In Chapter 6, we also see that a microservice architecture, with some modifications, gives each team the ability to deploy their service independently from other teams, to have multiple versions of a service in production simultaneously, and to roll back to a prior version relatively easily.

Figure 4.1 describes the situation that results from using a microservice architecture. A user interacts with a single consumer-facing service. This service, in turn, utilizes a collection of other services. We use the terminology *service* to refer to a component that provides a service and *client* to refer to a component that requests a service. A single component can be a client in one interaction and a service in another. In a system such as LinkedIn, the service depth may reach as much as 70 for a single user request.

Having an architecture composed of small services is a response to having small teams. Now we look at the aspects of an architecture that can be specified globally as a response to the requirement that inter-team coordination be minimized. We discuss three categories of design decisions that can be made globally as a portion of the architecture design, thus removing the need for inter-team

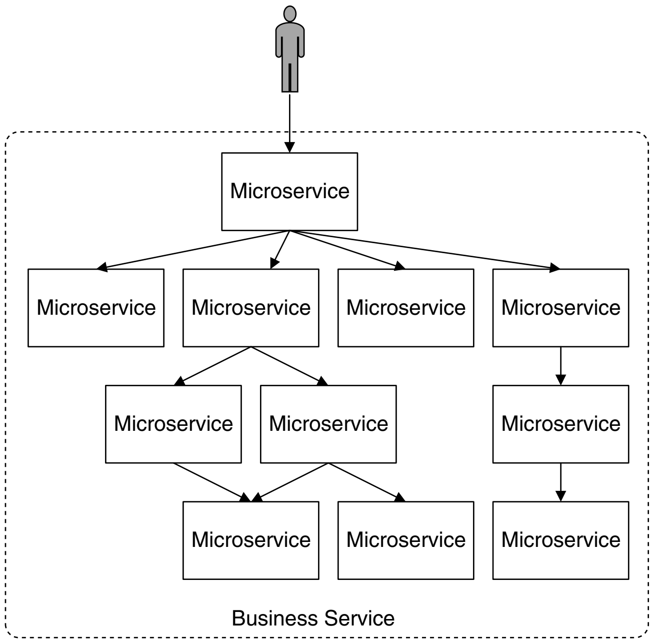

FIGURE 4.1 User interacting with a single service that, in turn, utilizes multiple other services [Notation: Architecture]

coordination with respect to these decisions. The three categories are: the coordination model, management of resources, and mapping among architectural elements.

Coordination Model

If two services interact, the two development teams responsible for those services must coordinate in some fashion. Two details of the coordination model that can be included in the overall architecture are: how a client discovers a service that it wishes to use, and how the individual services communicate.

Figure 4.2 gives an overview of the interaction between a service and its client. The service registers with a registry. The registration includes a name for the service as well as information on how to invoke it, for example, an endpoint location as a URL or an IP address. A client can retrieve the information about the service from the registry and invoke the service using this information. If the registry provides IP addresses, it acts as a local DNS server—local, because typically, the registry is not open to the general Internet but is within the environment of the application. Netflix Eureka is an example of a cloud service registry that acts as a DNS server. The registry serves as a catalogue of available services, and

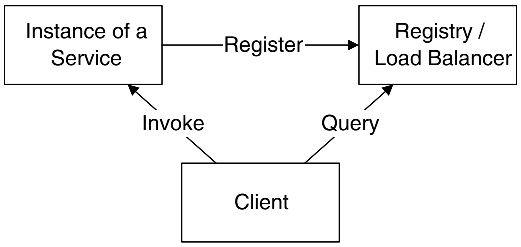

FIGURE 4.2 An instance of a service registers itself with the registry, the client queries the registry for the address of the service and invokes the service. [Notation: Architecture]

can further be used to track aspects such as versioning, ownership, service level agreements (SLAs), etc., for the set of services in an organization. We discuss extensions to the registry further in Chapter 6.

There will typically be multiple instances of a service, both to support a load too heavy for a single instance and to guard against failure. The registry can rotate among the instances registered to balance the load. That is, the registry acts as a load balancer as well as a registry. Finally, consider the possibility that an instance of a service may fail. In this case, the registry should not direct the client to the failed instance. By requiring the service to periodically renew its registration or proactively checking the health of the service, a guard against failure is put in place. If the service fails to renew its registration within the specified period, it is removed from the registry. Multiple instances of the service typically exist, and so the failure of one instance does not remove the service. The above-mentioned Netflix Eureka is an example for a registry offering load balancing. Eureka supports the requirement that services periodically renew their registration.

The protocol used for communication between the client and the service can be any remote communication protocol, for example, HTTP, RPC, SOAP, etc. The service can provide a RESTful interface or not. The remote communication protocol should be the only means for communication among the services. The details of the interface provided by the service still require cross-team coordination. When we discuss the example of Amazon later, we will see one method of providing this coordination. We will also see an explicit requirement for restricting communication among services to the remote communication protocol.

Management of Resources

Two types of resource management decisions can be made globally and incorporated in the architecture—provisioning/deprovisioning VMs and managing variation in demand.

Provisioning and Deprovisioning VMs

New VMs can be created in response to client demand or to failure. When the demand subsides, instances should be deprovisioned. If the instances are stateless (i.e., they do not retain any information between requests), a new instance can be placed into service as soon as it is provisioned. Similarly, if no state is kept in an instance, deprovisioning becomes relatively painless: After a cool-down period where the instance receives no new requests and responds to existing ones, the instance can be deprovisioned. The cool-down period should therefore be long enough for an instance to respond to all requests it received (i.e., the backlog). If you deprovision an instance due to reduced demand, the backlog should be fairly small—in any other case this action needs to be considered carefully. An additional advantage of a stateless service is that messages can be routed to any instance of that service, which facilitates load sharing among the instances.

This leads to a global decision to maintain state external to a service instance. As discussed in Chapter 2, large amounts of application state can be maintained in persistent storage, small amounts of application state can be maintained by tools such as ZooKeeper, and client state should not be maintained on the provider's side anyway.

Determining which component controls the provisioning and deprovisioning of a new instance for a service is another important aspect. Three possibilities exist for the controlling component.

1. A service itself can be responsible for (de)provisioning additional instances. A service can know its own queue lengths and its own performance in response to requests. It can compare these metrics to thresholds and (de)provision an instance itself if the threshold is crossed. Assuming that the distribution of requests is fair, in some sense, across all instances of the service, one particular instance (e.g., the oldest one) of the service can make the decision when to provision or deprovision instances. Thus, the service is allowed to expand or shrink capacity to meet demand.
2. A client or a component in the client chain can be responsible for (de)provisioning instances of a service. For instance, the client, based on the demands on it, may be aware that it will shortly be making demands on the service that exceed a given threshold and provisions new instances of the service.
3. An external component monitors the performance of service instances (e.g., their CPU load) and (de)provisions an instance when the load reaches a given threshold. Amazon's autoscaling groups provide this capability, in collaboration with the CloudWatch monitoring system.

Managing Demand

The number of instances of an individual service that exist should reflect the demand on the service from client requests. We just discussed several different methods for provisioning and deprovisioning instances, and these methods make different assumptions about how demand is managed.

- One method for managing demand is to monitor performance. Other decisions to be made include determining how to implement monitoring (e.g., whether done internally by running a monitoring agent inside each service instance or externally by a specialized component). That is, when demand grows that needs to be detected, a new instance can be provisioned. It takes time to provision a new instance, so it is important that the indicators are timely and even predictive to accommodate for that time. We discuss more details about monitoring in Chapter 7.
- Another possible technique is to use SLAs to control the number of instances. Each instance of the service guarantees through its SLAs that it is able to handle a certain number of requests with a specified latency. The clients of that service then know how many requests they can send and still receive a response within the specified latency. This technique has several constraints. First, it is likely that the requirements that a client imposes on your service will depend on the requirements imposed on the client, so there is a cascading effect up through the demand chain. This cascading will cause uncertainty in both the specification and the realization of the SLAs. A second constraint of the SLA technique is that each instance of your service may know how many requests it can handle, but the client has multiple available instances of your service. Thus, the provisioning component has to know how many instances currently exist of your service.

Mapping Among Architectural Elements

The final type of coordination decision that can be specified in the architecture is the mapping among architectural elements. We discuss two different types of mappings—work assignments and allocation. Both of these are decisions that are made globally.

- *Work assignments*. A single team may work on multiple modules, but having multiple development teams work on the same module requires a great deal of coordination among those development teams. Since coordination takes time, an easier structure is to package the work of a single team into modules and develop interfaces among the modules to allow modules developed by different teams to interoperate. In fact, the original definition of a module by David Parnas in the 1970s was as a work assignment of a team. Although not required, it is reasonable that each component (i.e., microservice) is the responsibility of a single development team. That is, the set of modules that, when linked, constitute a component are the output of a single development team. This does not preclude a single development team from being responsible for multiple components but it means that any coordination involving a component is settled within a single development team, and that any coordination involving multiple development teams goes across components. Given the set of constraints on the architecture we are describing, cross-team coordination requirements are limited.

- *Allocation*. Each component (i.e., microservice) will exist as an independent deployable unit. This allows each component to be allocated to a single (virtual) machine or container, or it allows multiple components to be allocated to a single (virtual) machine. The redeployment or upgrade of one microservice will not affect any other microservices. We explore this choice in Chapter 6.

4.3 Quality Discussion of Microservice Architecture

We have described an architectural style—microservice architecture—that reduces the necessity for inter-team coordination by making global architectural choices. The style provides some support for the qualities of dependability (stateless services) and modifiability (small services), but there are additional practices that a team should use to improve both dependability and modifiability of their services.

Dependability

Three sources for dependability problems are: the small amount of inter-team coordination, correctness of environment, and the possibility that an instance of a service can fail.

Small Amount of Inter-team Coordination

The limited amount of inter-team coordination may cause misunderstandings between the team developing a client and the team developing a service in terms of the semantics of an interface. In particular, unexpected input to a service or unexpected output from a service can happen. There are several options. First, a team should practice defensive programming and not assume that the input or the results of a service invocation are correct. Checking values for reasonableness will help detect errors early. Providing a rich collection of exceptions will enable faster determination of the cause of an error. Second, integration and end-to-end testing with all or most microservices should be done judiciously. It can be expensive to run these tests frequently due to the involvement of a potentially large number of microservices and realistic external resources. A testing practice called Consumer Driven Contract (CDC) can be used to alleviate the problem.

That is, the test cases for testing a microservice are decided and even co-owned by all the *consumers* of that microservice. Any changes to the CDC test cases need to be agreed on by both the consumers and the developers of the microservice. Running the CDC test cases, as a form of integration testing, is less expensive than running end-to-end test cases. If CDC is practiced properly, confidence in the microservice can be high without running many end-to-end test cases.

CDC serves as a method of coordination and has implications on how user stories of a microservice should be made up and evolve over time. Consumers and microservice developers collectively make up and own the user stories. CDC definition becomes a function of the allocation of functionality to the microservice, is managed by the service owner as a portion of the coordination that defines the next iteration, and, consequently, does not delay the progress of the current iteration.

Correctness of Environment

A service will operate in multiple different environments during the passage from unit test to post-production. Each environment is provisioned and maintained through code and a collection of configuration parameters. Errors in code and configuration parameters are quite common. Inconsistent configuration parameters are also possible. Due to a degree of uncertainty in cloud-based infrastructure, even executing the correct code and configuration may lead to an incorrect environment. Thus, the initialization portion of a service should test its current environment to determine whether it is as expected. It should also test the configuration parameters to detect, as far as possible, unexpected inconsistencies from different environments. If the behavior of the service depends on its environment (e.g., certain actions are performed during unit test but not during production), then the initialization should determine the environment and provide the settings for turning on or off the behavior. An important trend in DevOps is to manage all the code and parameters for setting up an environment just as you manage your application code, with proper version control and testing. This is an example of "infrastructure-as-code" as defined in Chapter 1 and discussed in more detail in Chapter 5. The testing of infrastructure code is a particularly challenging issue. We discuss the issues in Chapters 7 and 9.

Failure of an Instance

Failure is always a possibility for instances. An instance is deployed onto a physical machine, either directly or through the use of virtualization, and in large datacenters, the failure of a physical machine is common. The standard method through which a client detects the failure of an instance of a service is through the timeout of a request. Once a timeout has occurred, the client can issue a request again and, depending on the routing mechanism used, assume it is routed to a different instance of the service. In the case of multiple timeouts, the service is assumed to have failed and an alternative means of achieving the desired goal can be attempted.

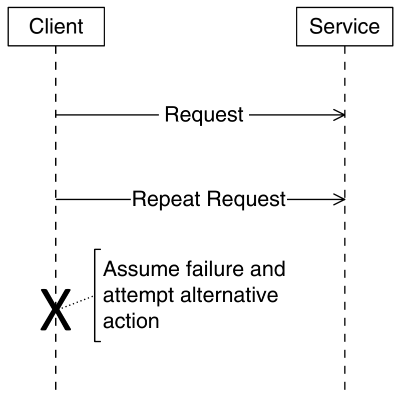

FIGURE 4.3 Time line in recognizing failure of a dependent service [Notation: UML Sequence Diagram]

Figure 4.3 shows a time line for a client attempting to access a failed service. The client makes a request to the service, and it times out. The client repeats the request, and it times out again. At this point, recognizing the failure has taken twice the timeout interval. Having a short timeout interval (failing fast) will enable a more rapid response to the client of the client requesting the service. A short timeout interval may, however, introduce false positives in that the service instance may just be slow for some reason. The result may be that both initial requests for service actually deliver the service, just not in a timely fashion. Another result may be that the alternative action is performed as well. Services should be designed so that multiple invocations of the same service will not introduce an error. *Idempotent* is the term for a service that can be repeatedly invoked with the same input and always produces the same output—namely, no error is generated.

Another point highlighted in Figure 4.3 is that the service has an alternative action. That is, the client has an alternative action in case the service fails. Figure 4.3 does not show what happens if there is no alternative action. In this case, the service reports failure to its client together with context information—namely, no response from the particular underlying service. We explore the topic of reporting errors in more depth in Chapter 7.

Modifiability

Making a service modifiable comes down to making likely changes easy and reducing the ripple effects of those changes. In both cases, a method for making the service more modifiable is to encapsulate either the affected portions of a likely change or the interactions that might cause ripple effects of a change.

Identifying Likely Changes

Some likely changes that come from the development process, rather than the service being provided, are:

- *The environments within which a service executes*. A module goes through unit tests in one environment, integration tests in another, acceptance tests in a third, and is in production in a fourth.
- *The state of other services with which your service interacts*. If other services are in the process of development, then the interfaces and semantics of those services are likely to change relatively quickly. Since you may not know the state of the external service, a safe practice is to treat, as much as possible, all communication with external services as likely to change.
- *The version of third-party software and libraries that are used by your service*. Third-party software and libraries can change arbitrarily, sometimes in ways that are disruptive for your service. In one case we heard, an external system removed an essential interface during the time the deployment process was ongoing. Using the same VM image in different environments will protect against those changes that are contained within the VM but not against external system changes.

Reducing Ripple Effects

Once likely changes have been discovered, you should prevent these types of changes from rippling through your service. This is typically done by introducing modules whose sole purpose is to localize and isolate changes to the environment, to other services, or to third-party software or libraries. The remainder of your service interacts with these changeable entities through the newly introduced modules with stable interfaces.

Any interaction with other services, for example, is mediated by the special module. Changes to the other services are reflected in the mediating module and buffered from rippling to the remainder of your service. Semantic changes to other services may, in fact, ripple, but the mediating module can absorb some of the impact, thereby reducing this ripple effect.

4.4 Amazon's Rules for Teams

As we mentioned in Chapter 1, Amazon has a rule that no team should be larger than can be fed with two pizzas; in the early years of this century they adopted an internal microservice architecture. Associated with the adoption was a list of rules to follow about how to use the services:

- "All teams will henceforth expose their data and functionality through service interfaces.
- Teams must communicate with each other through these interfaces.
- There will be no other form of inter-service/team communication allowed: no direct linking, no direct reads of another team's datastore, no shared-memory model, no backdoors whatsoever. The only communication allowed is via service interface calls over the network.
- It doesn't matter what technology they [other services] use.
- All service interfaces, without exception, must be designed from the ground up to be externalizable. That is to say, the team must plan and design to be able to expose the interface to developers in the outside world."

Each team produces some number of services. Every service is totally encapsulated except for its public interface. If another team wishes to use a service, it must discover the interface. The documentation for the interface must include enough semantic information to enable the user of a service to determine appropriate definitions for items such as "customer" or "address." These concepts can sometimes have differing meanings within different portions of an organization. The semantic information about an interface can be kept in the registry/load balancer that we described earlier, assuming that the semantic information is machine interpretable.

By making every service potentially externally available, whether or not to offer a service globally or keep it local becomes a business decision, not a technical one. External services can be hidden behind an application programming interface (API) bound through a library, and so this requirement is not prejudging the technology used for the interface.

A consequence of these rules is that Amazon has an extensive collection of services. A web page from their sales business makes use of over 150 services. Scalability is managed by each service individually and is included in its SLA in the form of a guaranteed response time given a particular load. The contract covers what the service promises against certain demand levels. The SLA binds both the client side and the service side. If the client's demand exceeds the load promised in the SLA, then slow response times become the client's problem, not the service's.

4.5 Microservice Adoption for Existing Systems

Although microservices reflect the small, independent team philosophy of DevOps, most organizations have large mission-critical systems that are not architected that way. These organizations need to decide whether to migrate their architectures to microservice architectures, and which ones to migrate. We discuss this migration somewhat in Chapter 10. Some of the things an architect thinking of adopting a microservice architecture should ensure are the following:

- Operational concerns are considered during requirements specification.
- The overarching structure of the system being developed should be a collection of small, independent services.
- Each service should be distrustful of both clients and other required services.
- Team roles have been defined and are understood.
- Services are required to be registered with a local registry/load balancer.
- Services must renew their registration periodically.
- Services must provide SLAs for their clients.
- Services should aim to be stateless and be treated as transient.
- If a service has to maintain state, it should be maintained in external persistent storage.
- Services have alternatives in case a service they depend on fails.
- Services have defensive checks to intercept erroneous input from clients and output from other services.
- Uses of external services, environmental information, and third-party software and libraries are localized (i.e., they require passage through a module specific to that external service, environment information, or external software or library).

However, adopting a microservice architecture will introduce new challenges. When an application is composed of a large number of network-connected microservices, there can be latency and other performance issues. Authentication and authorization between services need to be carefully designed so that they do not add intolerable overhead. Monitoring, debugging, and distributed tracing tools may need to be modified to suit microservices. As mentioned earlier, end-to-end testing will be expensive. Rarely can you rebuild your application from scratch without legacy components or existing data.

Migrating from your current architecture to a microservice architecture incrementally without data loss and interruption is a challenge. You may need to build interim solutions during this migration. We discuss these challenges and some solutions in the Atlassian case study in Chapter 13, wherein Atlassian describes the initial steps of their journey to a microservice architecture. An architect should have a checklist of things to consider when performing a migration.

4.6 Summary

The DevOps goal of minimizing coordination among various teams can be achieved by using a microservice architectural style where the coordination mechanism, the resource management decisions, and the mapping of architectural elements are all specified by the architecture and hence require minimal inter-team coordination.

A collection of practices for development can be added to the microservice architectural style to achieve dependability and modifiability, such as identifying and isolating areas of likely change.

Adopting a microservice architectural style introduces additional challenges in monitoring, debugging, performance management, and testing. Migrating from an existing architecture to a microservice architectural style requires careful planning and commitment.

4.7 For Further Reading

For more information about software architecture, we recommend the following books:

- *Documenting Software Architectures, 2nd Edition* [Clements 10]
- *Software Architecture in Practice, 3rd Edition* [Bass 13]

Service description, cataloguing, and management are discussed in detail in the *Handbook of Service Description* [Barros 12]. This book describes services that are externally visible, not microservices, but much of the discussion is relevant to microservices as well.

The microservice architectural style is described in the book *Building Microservices: Designing Fine-Grained Systems* [Newman 15].

Many organizations are already practicing a version of the microservice architectural development and DevOps, and sharing their valuable experiences.

- You can read more about the Amazon example here: http://apievangelist.com/2012/01/12/the-secret-to-amazons-success-internal-apis/ and http://www.zdnet.com/blog/storage/soa-done-right-the-amazon-strategy/152
- Netflix points out some challenges in using microservice architecture at scale [Tonse 14].

The Netflix implementation of Eureka—their open source internal load balancer/registry—can be found at https://github.com/Netflix/eureka/wiki/Eureka-at-a-glance

Consumer Driven Contracts (CDCs) are discussed in Martin Fowler's blog "Consumer-Driven Contracts: A Service Evolution Pattern," [Fowler 06].

About the Authors

Len Bass is a senior principal researcher at National ICT Australia Ltd. (NICTA). He joined NICTA in 2011 after 25 years at the Software Engineering Institute (SEI) at Carnegie Mellon University. He is the coauthor of two award-winning books in software architecture—*Software Architecture in Practice, Third Edition* (Addison-Wesley 2013) and *Documenting Software Architectures: Views and Beyond*, *Second Edition* (Addison-Wesley 2011)—as well as several other books and numerous papers in computer science and software engineering on a wide range of topics. Len has more than 50 years' experience in software development and research, which has resulted in papers on operating systems, database management systems, user interface software, software architecture, product line systems, and computer operations. He has worked or consulted in multiple domains, including scientific analysis, embedded systems, and information and financial systems.

Ingo Weber is a senior researcher in the Software Systems Research Group at NICTA in Sydney, Australia, as well as an adjunct senior lecturer at CSE at the University of New South Wales (UNSW). Prior to NICTA, Ingo held positions at UNSW and at SAP Research Karlsruhe, Germany. His research interests include cloud computing, DevOps, business process management, and artificial intelligence (AI). He has published over 60 peer-reviewed papers, and served as a reviewer or program committee member for many prestigious scientific journals and conferences. Ingo holds a Ph.D. and a Diploma from the University of Karlsruhe, and an MSc from the University of Massachusetts at Amherst.

Liming Zhu is a research group leader and principal researcher at NICTA. He holds conjoint positions at the University of New South Wales (UNSW) and the University of Sydney. Liming has published over 80 peer-reviewed papers. He formerly worked in several technology lead positions in the software industry before obtaining a Ph.D. in software engineering from UNSW. He is a committee member of the Standards Australia IT-015 (system and software engineering), contributing to ISO/SC7. Liming's research interests include software architecture and dependable systems.

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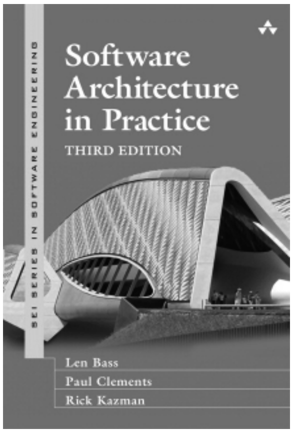
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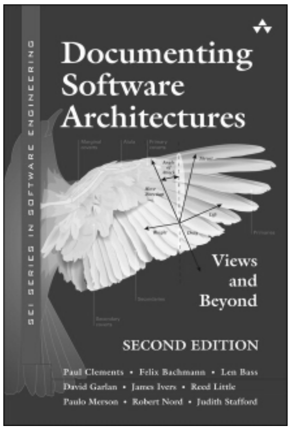
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