But reality is not that simple. There are many database systems with different characteristics, because different applications have different requirements. There are various approaches to caching, several ways of building search indexes, and so on. When building an application, we still need to figure out which tools and which approaches are the most appropriate for the task at hand. And it can be hard to combine tools when you need to do something that a single tool cannot do alone.

This book is a journey through both the principles and the practicalities of data systems, and how you can use them to build data-intensive applications. We will explore what different tools have in common, what distinguishes them, and how they achieve their characteristics.

In this chapter, we will start by exploring the fundamentals of what we are trying to achieve: reliable, scalable, and maintainable data systems. We'll clarify what those things mean, outline some ways of thinking about them, and go over the basics that we will need for later chapters. In the following chapters we will continue layer by layer, looking at different design decisions that need to be considered when working on a data-intensive application.

Thinking About Data Systems

We typically think of databases, queues, caches, etc. as being very different categories of tools. Although a database and a message queue have some superficial similarity—both store data for some time—they have very different access patterns, which means different performance characteristics, and thus very different implementations.

So why should we lump them all together under an umbrella term like *data systems*?

Many new tools for data storage and processing have emerged in recent years. They are optimized for a variety of different use cases, and they no longer neatly fit into traditional categories [1]. For example, there are datastores that are also used as message queues (Redis), and there are message queues with database-like durability guarantees (Apache Kafka). The boundaries between the categories are becoming blurred.

Secondly, increasingly many applications now have such demanding or wide-ranging requirements that a single tool can no longer meet all of its data processing and storage needs. Instead, the work is broken down into tasks that *can* be performed efficiently on a single tool, and those different tools are stitched together using application code.

For example, if you have an application-managed caching layer (using Memcached or similar), or a full-text search server (such as Elasticsearch or Solr) separate from your main database, it is normally the application code's responsibility to keep those caches and indexes in sync with the main database. Figure 1-1 gives a glimpse of what this may look like (we will go into detail in later chapters).

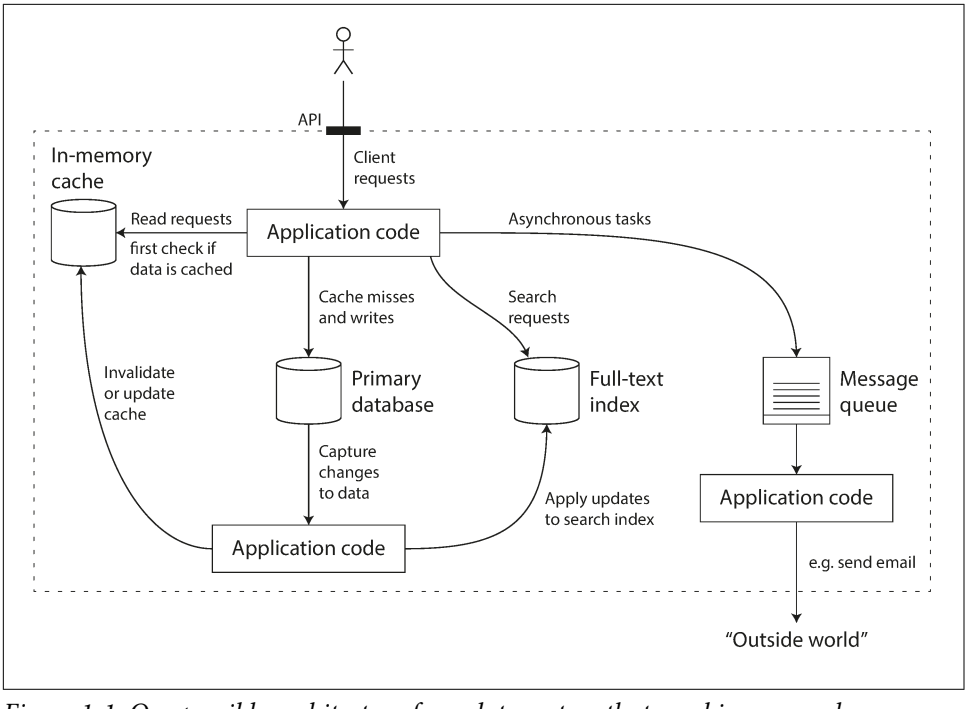

Figure 1-1. One possible architecture for a data system that combines several components.

When you combine several tools in order to provide a service, the service's interface or application programming interface (API) usually hides those implementation details from clients. Now you have essentially created a new, special-purpose data system from smaller, general-purpose components. Your composite data system may provide certain guarantees: e.g., that the cache will be correctly invalidated or updated on writes so that outside clients see consistent results. You are now not only an application developer, but also a data system designer.

If you are designing a data system or service, a lot of tricky questions arise. How do you ensure that the data remains correct and complete, even when things go wrong internally? How do you provide consistently good performance to clients, even when parts of your system are degraded? How do you scale to handle an increase in load? What does a good API for the service look like?

There are many factors that may influence the design of a data system, including the skills and experience of the people involved, legacy system dependencies, the timescale for delivery, your organization's tolerance of different kinds of risk, regulatory constraints, etc. Those factors depend very much on the situation.

In this book, we focus on three concerns that are important in most software systems:

Reliability
: The system should continue to work *correctly* (performing the correct function at the desired level of performance) even in the face of *adversity* (hardware or software faults, and even human error). See "Reliability" on page 6.

Scalability
: As the system *grows* (in data volume, traffic volume, or complexity), there should be reasonable ways of dealing with that growth. See "Scalability" on page 10.

Maintainability
: Over time, many different people will work on the system (engineering and operations, both maintaining current behavior and adapting the system to new use cases), and they should all be able to work on it *productively*. See "Maintainability" on page 18.

These words are often cast around without a clear understanding of what they mean. In the interest of thoughtful engineering, we will spend the rest of this chapter exploring ways of thinking about reliability, scalability, and maintainability. Then, in the following chapters, we will look at various techniques, architectures, and algorithms that are used in order to achieve those goals.

Reliability

Everybody has an intuitive idea of what it means for something to be reliable or unreliable. For software, typical expectations include:

- The application performs the function that the user expected.
- It can tolerate the user making mistakes or using the software in unexpected ways.
- Its performance is good enough for the required use case, under the expected load and data volume.
- The system prevents any unauthorized access and abuse.

If all those things together mean "working correctly," then we can understand *reliability* as meaning, roughly, "continuing to work correctly, even when things go wrong."

The things that can go wrong are called *faults*, and systems that anticipate faults and can cope with them are called *fault-tolerant* or *resilient*. The former term is slightly misleading: it suggests that we could make a system tolerant of every possible kind of fault, which in reality is not feasible. If the entire planet Earth (and all servers on it) were swallowed by a black hole, tolerance of that fault would require web hosting in