

Pramod J. Sadalage

Martin Fowler



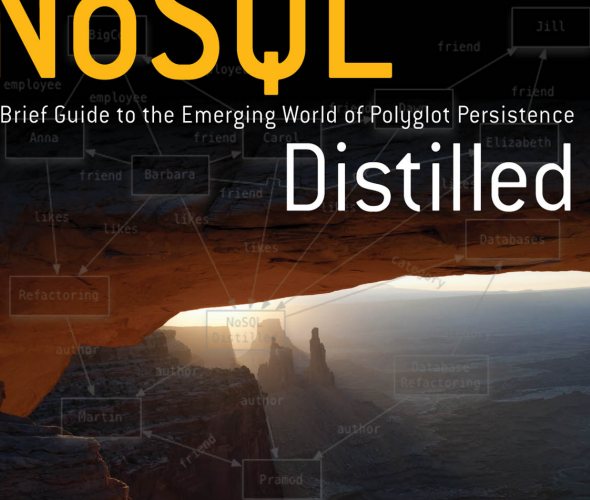
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# NoSQL

A Brief Guide to the Emerging World of Polyglot Persistence

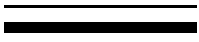
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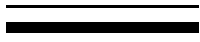
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# NoSQL Distilled

## A Brief Guide to the Emerging World of Polyglot Persistence

Pramod J. Sadalage

Martin Fowler

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*For my teachers Gajanan Chinchwadkar,  
Dattatraya Mhaskar, and Arvind Parchure. You  
inspired me the most, thank you.*

*—Pramod*

*For Cindy*

*—Martin*

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# Contents

Preface .....	xiii
Part I: Understand .....	1
<b>Chapter 1: Why NoSQL?</b> .....	<b>3</b>
1.1 The Value of Relational Databases .....	3
1.1.1 <i>Getting at Persistent Data</i> .....	3
1.1.2 <i>Concurrency</i> .....	4
1.1.3 <i>Integration</i> .....	4
1.1.4 <i>A (Mostly) Standard Model</i> .....	4
1.2 Impedance Mismatch .....	5
1.3 Application and Integration Databases .....	6
1.4 Attack of the Clusters .....	8
1.5 The Emergence of NoSQL .....	9
1.6 Key Points .....	12
<b>Chapter 2: Aggregate Data Models</b> .....	<b>13</b>
2.1 Aggregates .....	14
2.1.1 <i>Example of Relations and Aggregates</i> .....	14
2.1.2 <i>Consequences of Aggregate Orientation</i> .....	19
2.2 Key-Value and Document Data Models .....	20
2.3 Column-Family Stores .....	21
2.4 Summarizing Aggregate-Oriented Databases .....	23
2.5 Further Reading .....	24
2.6 Key Points .....	24
<b>Chapter 3: More Details on Data Models</b> .....	<b>25</b>
3.1 Relationships .....	25
3.2 Graph Databases .....	26



3.3	Schemaless Databases .....	28
3.4	Materialized Views .....	30
3.5	Modeling for Data Access .....	31
3.6	Key Points .....	36
<b>Chapter 4:</b>	<b>Distribution Models .....</b>	<b>37</b>
4.1	Single Server .....	37
4.2	Sharding .....	38
4.3	Master-Slave Replication .....	40
4.4	Peer-to-Peer Replication .....	42
4.5	Combining Sharding and Replication .....	43
4.6	Key Points .....	44
<b>Chapter 5:</b>	<b>Consistency .....</b>	<b>47</b>
5.1	Update Consistency .....	47
5.2	Read Consistency .....	49
5.3	Relaxing Consistency .....	52
5.3.1	<i>The CAP Theorem</i> .....	53
5.4	Relaxing Durability .....	56
5.5	Quorums .....	57
5.6	Further Reading .....	59
5.7	Key Points .....	59
<b>Chapter 6:</b>	<b>Version Stamps .....</b>	<b>61</b>
6.1	Business and System Transactions .....	61
6.2	Version Stamps on Multiple Nodes .....	63
6.3	Key Points .....	65
<b>Chapter 7:</b>	<b>Map-Reduce .....</b>	<b>67</b>
7.1	Basic Map-Reduce .....	68
7.2	Partitioning and Combining .....	69
7.3	Composing Map-Reduce Calculations .....	72
7.3.1	<i>A Two Stage Map-Reduce Example</i> .....	73
7.3.2	<i>Incremental Map-Reduce</i> .....	76
7.4	Further Reading .....	77
7.5	Key Points .....	77
<b>Part II:</b>	<b>Implement .....</b>	<b>79</b>
<b>Chapter 8:</b>	<b>Key-Value Databases .....</b>	<b>81</b>
8.1	What Is a Key-Value Store .....	81
8.2	Key-Value Store Features .....	83

8.2.1	<i>Consistency</i> .....	83
8.2.2	<i>Transactions</i> .....	84
8.2.3	<i>Query Features</i> .....	84
8.2.4	<i>Structure of Data</i> .....	86
8.2.5	<i>Scaling</i> .....	86
8.3	<b>Suitable Use Cases</b> .....	87
8.3.1	<i>Storing Session Information</i> .....	87
8.3.2	<i>User Profiles, Preferences</i> .....	87
8.3.3	<i>Shopping Cart Data</i> .....	87
8.4	<b>When Not to Use</b> .....	87
8.4.1	<i>Relationships among Data</i> .....	87
8.4.2	<i>Multioperation Transactions</i> .....	88
8.4.3	<i>Query by Data</i> .....	88
8.4.4	<i>Operations by Sets</i> .....	88
	<b>Chapter 9: Document Databases</b> .....	89
9.1	<b>What Is a Document Database?</b> .....	90
9.2	<b>Features</b> .....	91
9.2.1	<i>Consistency</i> .....	91
9.2.2	<i>Transactions</i> .....	92
9.2.3	<i>Availability</i> .....	93
9.2.4	<i>Query Features</i> .....	94
9.2.5	<i>Scaling</i> .....	95
9.3	<b>Suitable Use Cases</b> .....	97
9.3.1	<i>Event Logging</i> .....	97
9.3.2	<i>Content Management Systems, Blogging Platforms</i> .....	98
9.3.3	<i>Web Analytics or Real-Time Analytics</i> .....	98
9.3.4	<i>E-Commerce Applications</i> .....	98
9.4	<b>When Not to Use</b> .....	98
9.4.1	<i>Complex Transactions Spanning Different Operations</i> .....	98
9.4.2	<i>Queries against Varying Aggregate Structure</i> .....	98
	<b>Chapter 10: Column-Family Stores</b> .....	99
10.1	<b>What Is a Column-Family Data Store?</b> .....	99
10.2	<b>Features</b> .....	100
10.2.1	<i>Consistency</i> .....	103
10.2.2	<i>Transactions</i> .....	104
10.2.3	<i>Availability</i> .....	104

10.2.4	<i>Query Features</i> .....	105
10.2.5	<i>Scaling</i> .....	107
10.3	<b>Suitable Use Cases</b> .....	107
10.3.1	<i>Event Logging</i> .....	107
10.3.2	<i>Content Management Systems, Blogging Platforms</i> .....	108
10.3.3	<i>Counters</i> .....	108
10.3.4	<i>Expiring Usage</i> .....	108
10.4	<b>When Not to Use</b> .....	109
<b>Chapter 11:</b>	<b>Graph Databases</b> .....	<b>111</b>
11.1	<b>What Is a Graph Database?</b> .....	111
11.2	<b>Features</b> .....	113
11.2.1	<i>Consistency</i> .....	114
11.2.2	<i>Transactions</i> .....	114
11.2.3	<i>Availability</i> .....	115
11.2.4	<i>Query Features</i> .....	115
11.2.5	<i>Scaling</i> .....	119
11.3	<b>Suitable Use Cases</b> .....	120
11.3.1	<i>Connected Data</i> .....	120
11.3.2	<i>Routing, Dispatch, and Location-Based Services</i> .....	120
11.3.3	<i>Recommendation Engines</i> .....	121
11.4	<b>When Not to Use</b> .....	121
<b>Chapter 12:</b>	<b>Schema Migrations</b> .....	<b>123</b>
12.1	<b>Schema Changes</b> .....	123
12.2	<b>Schema Changes in RDBMS</b> .....	123
12.2.1	<i>Migrations for Green Field Projects</i> .....	124
12.2.2	<i>Migrations in Legacy Projects</i> .....	126
12.3	<b>Schema Changes in a NoSQL Data Store</b> .....	128
12.3.1	<i>Incremental Migration</i> .....	130
12.3.2	<i>Migrations in Graph Databases</i> .....	131
12.3.3	<i>Changing Aggregate Structure</i> .....	132
12.4	<b>Further Reading</b> .....	132
12.5	<b>Key Points</b> .....	132
<b>Chapter 13:</b>	<b>Polyglot Persistence</b> .....	<b>133</b>
13.1	<b>Disparate Data Storage Needs</b> .....	133
13.2	<b>Polyglot Data Store Usage</b> .....	134
13.3	<b>Service Usage over Direct Data Store Usage</b> .....	136

13.4	Expanding for Better Functionality .....	136
13.5	Choosing the Right Technology .....	138
13.6	Enterprise Concerns with Polyglot Persistence .....	138
13.7	Deployment Complexity .....	139
13.8	Key Points .....	140
<b>Chapter 14:</b>	<b>Beyond NoSQL .....</b>	<b>141</b>
14.1	File Systems .....	141
14.2	Event Sourcing .....	142
14.3	Memory Image .....	144
14.4	Version Control .....	145
14.5	XML Databases .....	145
14.6	Object Databases .....	146
14.7	Key Points .....	146
<b>Chapter 15:</b>	<b>Choosing Your Database .....</b>	<b>147</b>
15.1	Programmer Productivity .....	147
15.2	Data-Access Performance .....	149
15.3	Sticking with the Default .....	150
15.4	Hedging Your Bets .....	150
15.5	Key Points .....	151
15.6	Final Thoughts .....	152
<b>Bibliography</b>	.....	<b>153</b>
<b>Index</b>	.....	<b>157</b>

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# Preface

We've spent some twenty years in the world of enterprise computing. We've seen many things change in languages, architectures, platforms, and processes. But through all this time one thing has stayed constant—relational databases store the data. There have been challengers, some of which have had success in some niches, but on the whole the data storage question for architects has been the question of which relational database to use.

There is a lot of value in the stability of this reign. An organization's data lasts much longer than its programs (at least that's what people tell us—we've seen plenty of very old programs out there). It's valuable to have a stable data storage that's well understood and accessible from many application programming platforms.

Now, however, there's a new challenger on the block under the confrontational tag of NoSQL. It's born out of a need to handle larger data volumes which forced a fundamental shift to building large hardware platforms through clusters of commodity servers. This need has also raised long-running concerns about the difficulties of making application code play well with the relational data model.

The term “NoSQL” is very ill-defined. It's generally applied to a number of recent nonrelational databases such as Cassandra, Mongo, Neo4J, and Riak. They embrace schemaless data, run on clusters, and have the ability to trade off traditional consistency for other useful properties. Advocates of NoSQL databases claim that they can build systems that are more performant, scale much better, and are easier to program with.

Is this the first rattle of the death knell for relational databases, or yet another pretender to the throne? Our answer to that is “neither.” Relational databases are a powerful tool that we expect to be using for many more decades, but we do see a profound change in that relational databases won't be the only databases in use. Our view is that we are entering a world of Polyglot Persistence where enterprises, and even individual applications, use multiple technologies for data management. As a result, architects will need to be familiar with these technologies and be able to evaluate which ones to use for differing needs.

Had we not thought that, we wouldn't have spent the time and effort writing this book.

This book seeks to give you enough information to answer the question of whether NoSQL databases are worth serious consideration for your future projects. Every project is different, and there's no way we can write a simple decision tree to choose the right data store. Instead, what we are attempting here is to provide you with enough background on how NoSQL databases work, so that you can make those judgments yourself without having to trawl the whole web. We've deliberately made this a small book, so you can get this overview pretty quickly. It won't answer your questions definitively, but it should narrow down the range of options you have to consider and help you understand what questions you need to ask.

---

## Why Are NoSQL Databases Interesting?

We see two primary reasons why people consider using a NoSQL database.

- **Application development productivity.** A lot of application development effort is spent on mapping data between in-memory data structures and a relational database. A NoSQL database may provide a data model that better fits the application's needs, thus simplifying that interaction and resulting in less code to write, debug, and evolve.
- **Large-scale data.** Organizations are finding it valuable to capture more data and process it more quickly. They are finding it expensive, if even possible, to do so with relational databases. The primary reason is that a relational database is designed to run on a single machine, but it is usually more economic to run large data and computing loads on clusters of many smaller and cheaper machines. Many NoSQL databases are designed explicitly to run on clusters, so they make a better fit for big data scenarios.

---

## What's in the Book

We've broken this book up into two parts. The first part concentrates on core concepts that we think you need to know in order to judge whether NoSQL databases are relevant for you and how they differ. In the second part we concentrate more on implementing systems with NoSQL databases.

Chapter 1 begins by explaining why NoSQL has had such a rapid rise—the need to process larger data volumes led to a shift, in large systems, from scaling vertically to scaling horizontally on clusters. This explains an important feature of the data model of many NoSQL databases—the explicit storage of a rich structure of closely related data that is accessed as a unit. In this book we call this kind of structure an *aggregate*.

Chapter 2 describes how aggregates manifest themselves in three of the main data models in NoSQL land: key-value (“Key-Value and Document Data Models,” p. 20), document (“Key-Value and Document Data Models,” p. 20), and column family (“Column-Family Stores,” p. 21) databases. Aggregates provide a natural unit of interaction for many kinds of applications, which both improves running on a cluster and makes it easier to program the data access. Chapter 3 shifts to the downside of aggregates—the difficulty of handling relationships (“Relationships,” p. 25) between entities in different aggregates. This leads us naturally to graph databases (“Graph Databases,” p. 26), a NoSQL data model that doesn’t fit into the aggregate-oriented camp. We also look at the common characteristic of NoSQL databases that operate without a schema (“Schemaless Databases,” p. 28)—a feature that provides some greater flexibility, but not as much as you might first think.

Having covered the data-modeling aspect of NoSQL, we move on to distribution: Chapter 4 describes how databases distribute data to run on clusters. This breaks down into sharding (“Sharding,” p. 38) and replication, the latter being either master-slave (“Master-Slave Replication,” p. 40) or peer-to-peer (“Peer-to-Peer Replication,” p. 42) replication. With the distribution models defined, we can then move on to the issue of consistency. NoSQL databases provide a more varied range of consistency options than relational databases—which is a consequence of being friendly to clusters. So Chapter 5 talks about how consistency changes for updates (“Update Consistency,” p. 47) and reads (“Read Consistency,” p. 49), the role of quorums (“Quorums,” p. 57), and how even some durability (“Relaxing Durability,” p. 56) can be traded off. If you’ve heard anything about NoSQL, you’ll almost certainly have heard of the CAP theorem; the “The CAP Theorem” section on p. 53 explains what it is and how it fits in.

While these chapters concentrate primarily on the principles of how data gets distributed and kept consistent, the next two chapters talk about a couple of important tools that make this work. Chapter 6 describes version stamps, which are for keeping track of changes and detecting inconsistencies. Chapter 7 outlines map-reduce, which is a particular way of organizing parallel computation that fits in well with clusters and thus with NoSQL systems.

Once we’re done with concepts, we move to implementation issues by looking at some example databases under the four key categories: Chapter 8 uses Riak



as an example of key-value databases, Chapter 9 takes MongoDB as an example for document databases, Chapter 10 chooses Cassandra to explore column-family databases, and finally Chapter 11 plucks Neo4J as an example of graph databases. We must stress that this is not a comprehensive study—there are too many out there to write about, let alone for us to try. Nor does our choice of examples imply any recommendations. Our aim here is to give you a feel for the variety of stores that exist and for how different database technologies use the concepts we outlined earlier. You’ll see what kind of code you need to write to program against these systems and get a glimpse of the mindset you’ll need to use them.

A common statement about NoSQL databases is that since they have no schema, there is no difficulty in changing the structure of data during the life of an application. We disagree—a schemaless database still has an implicit schema that needs change discipline when you implement it, so Chapter 12 explains how to do data migration both for strong schemas and for schemaless systems.

All of this should make it clear that NoSQL is not a single thing, nor is it something that will replace relational databases. Chapter 13 looks at this future world of Polyglot Persistence, where multiple data-storage worlds coexist, even within the same application. Chapter 14 then expands our horizons beyond this book, considering other technologies that we haven’t covered that may also be a part of this polyglot-persistent world.

With all of this information, you are finally at a point where you can make a choice of what data storage technologies to use, so our final chapter (Chapter 15, “Choosing Your Database,” p. 147) offers some advice on how to think about these choices. In our view, there are two key factors—finding a productive programming model where the data storage model is well aligned to your application, and ensuring that you can get the data access performance and resilience you need. Since this is early days in the NoSQL life story, we’re afraid that we don’t have a well-defined procedure to follow, and you’ll need to test your options in the context of your needs.

This is a brief overview—we’ve been very deliberate in limiting the size of this book. We’ve selected the information we think is the most important—so that you don’t have to. If you are going to seriously investigate these technologies, you’ll need to go further than what we cover here, but we hope this book provides a good context to start you on your way.

We also need to stress that this is a very volatile field of the computer industry. Important aspects of these stores are changing every year—new features, new databases. We’ve made a strong effort to focus on concepts, which we think will be valuable to understand even as the underlying technology changes. We’re pretty confident that most of what we say will have this longevity, but absolutely sure that not all of it will.

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## Who Should Read This Book

Our target audience for this book is people who are considering using some form of a NoSQL database. This may be for a new project, or because they are hitting barriers that are suggesting a shift on an existing project.

Our aim is to give you enough information to know whether NoSQL technology makes sense for your needs, and if so which tool to explore in more depth. Our primary imagined audience is an architect or technical lead, but we think this book is also valuable for people involved in software management who want to get an overview of this new technology. We also think that if you're a developer who wants an overview of this technology, this book will be a good starting point.

We don't go into the details of programming and deploying specific databases here—we leave that for specialist books. We've also been very firm on a page limit, to keep this book a brief introduction. This is the kind of book we think you should be able to read on a plane flight: It won't answer all your questions but should give you a good set of questions to ask.

If you've already delved into the world of NoSQL, this book probably won't commit any new items to your store of knowledge. However, it may still be useful by helping you explain what you've learned to others. Making sense of the issues around NoSQL is important—particularly if you're trying to persuade someone to consider using NoSQL in a project.

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## What Are the Databases

In this book, we've followed a common approach of categorizing NoSQL databases according to their data model. Here is a table of the four data models and some of the databases that fit each model. This is not a comprehensive list—it only mentions the more common databases we've come across. At the time of writing, you can find more comprehensive lists at <http://nosql-database.org> and <http://nosql.mypopescu.com/kb/nosql>. For each category, we mark with italics the database we use as an example in the relevant chapter.

Our goal is to pick a representative tool from each of the categories of the databases. While we talk about specific examples, most of the discussion should apply to the entire category, even though these products are unique and cannot be generalized as such. We will pick one database for each of the key-value, document, column family, and graph databases; where appropriate, we will mention other products that may fulfill a specific feature need.

Data Model	Example Databases
Key-Value (“Key-Value Databases,” p. 81)	BerkeleyDB LevelDB Memcached Project Voldemort Redis <i>Riak</i>
Document (“Document Databases,” p. 89)	CouchDB <i>MongoDB</i> OrientDB RavenDB Terrastore
Column-Family (“Column-Family Stores,” p. 99)	Amazon SimpleDB <i>Cassandra</i> HBase Hypertable
Graph (“Graph Databases,” p. 111)	FlockDB HyperGraphDB Infinite Graph <i>Neo4J</i> OrientDB

This classification by data model is useful, but crude. The lines between the different data models, such as the distinction between key-value and document databases (“Key-Value and Document Data Models,” p. 20), are often blurry. Many databases don’t fit cleanly into categories; for example, OrientDB calls itself both a document database and a graph database.

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## Acknowledgments

Our first thanks go to our colleagues at ThoughtWorks, many of whom have been applying NoSQL to our delivery projects over the last couple of years. Their experiences have been a primary source both of our motivation in writing this book and of practical information on the value of this technology. The positive

experience we've had so far with NoSQL data stores is the basis of our view that this is an important technology and a significant shift in data storage.

We'd also like to thank various groups who have given public talks, published articles, and blogs on their use of NoSQL. Much progress in software development gets hidden when people don't share with their peers what they've learned. Particular thanks here go to Google and Amazon whose papers on Bigtable and Dynamo were very influential in getting the NoSQL movement going. We also thank companies that have sponsored and contributed to the open-source development of NoSQL databases. An interesting difference with previous shifts in data storage is the degree to which the NoSQL movement is rooted in open-source work.

Particular thanks go to ThoughtWorks for giving us the time to work on this book. We joined ThoughtWorks at around the same time and have been here for over a decade. ThoughtWorks continues to be a very hospitable home for us, a source of knowledge and practice, and a welcome environment of openly sharing what we learn—so different from the traditional systems delivery organizations.

Bethany Anders-Beck, Ilias Bartolini, Tim Berglund, Duncan Craig, Paul Duvall, Oren Eini, Perryn Fowler, Michael Hunger, Eric Kascic, Joshua Kerievsky, Anand Krishnaswamy, Bobby Norton, Ade Oshineye, Thiyagu Palanisamy, Prasanna Pendse, Dan Pritchett, David Rice, Mike Roberts, Marko Rodriguez, Andrew Slocum, Toby Tripp, Steve Vinoski, Dean Wampler, Jim Webber, and Wee Witthawaskul reviewed early drafts of this book and helped us improve it with their advice.

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# Chapter 13

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## Polyglot Persistence

Different databases are designed to solve different problems. Using a single database engine for all of the requirements usually leads to non-performant solutions; storing transactional data, caching session information, traversing graph of customers and the products their friends bought are essentially different problems. Even in the RDBMS space, the requirements of an OLAP and OLTP system are very different—nonetheless, they are often forced into the same schema.

Let's think of data relationships. RDBMS solutions are good at enforcing that relationships exist. If we want to discover relationships, or have to find data from different tables that belong to the same object, then the use of RDBMS starts being difficult.

Database engines are designed to perform certain operations on certain data structures and data amounts very well—such as operating on sets of data or a store and retrieving keys and their values really fast, or storing rich documents or complex graphs of information.

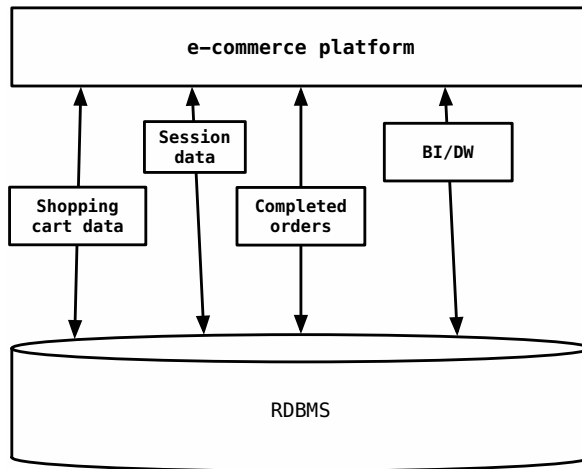
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### 13.1 Disparate Data Storage Needs

Many enterprises tend to use the same database engine to store business transactions, session management data, and for other storage needs such as reporting, BI, data warehousing, or logging information (Figure 13.1).

The session, shopping cart, or order data do not need the same properties of availability, consistency, or backup requirements. Does session management storage need the same rigorous backup/recovery strategy as the e-commerce orders data? Does the session management storage need more availability of an instance of database engine to write/read session data?

In 2006, Neal Ford coined the term **polyglot programming**, to express the idea that applications should be written in a mix of languages to take advantage



**Figure 13.1** *Use of RDBMS for every aspect of storage for the application*

of the fact that different languages are suitable for tackling different problems. Complex applications combine different types of problems, so picking the right language for each job may be more productive than trying to fit all aspects into a single language.

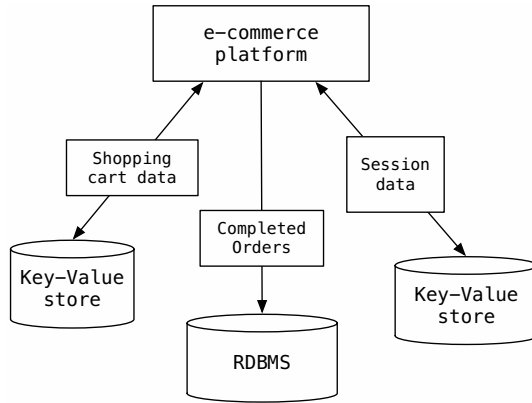
Similarly, when working on an e-commerce business problem, using a data store for the shopping cart which is highly available and can scale is important, but the same data store cannot help you find products bought by the customers' friends—which is a totally different question. We use the term **polyglot persistence** to define this hybrid approach to persistence.

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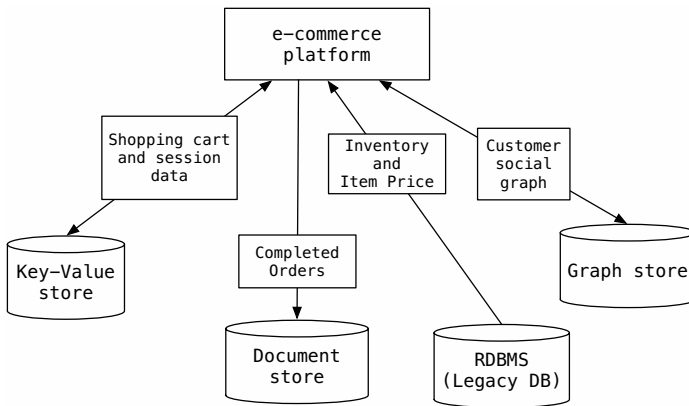
## 13.2 Polyglot Data Store Usage

Let's take our e-commerce example and use the polyglot persistence approach to see how some of these data stores can be applied (Figure 13.2). A key-value data store could be used to store the shopping cart data before the order is confirmed by the customer and also store the session data so that the RDBMS is not used for this transient data. Key-value stores make sense here since the shopping cart is usually accessed by user ID and, once confirmed and paid by the customer, can be saved in the RDBMS. Similarly, session data is keyed by the session ID.

If we need to recommend products to customers when they place products into their shopping carts—for example, “your friends also bought these products”



**Figure 13.2** Use of key-value stores to offload session and shopping cart data storage



**Figure 13.3** Example implementation of polyglot persistence

or “your friends bought these accessories for this product” — then introducing a graph data store in the mix becomes relevant (Figure 13.3).

It is not necessary for the application to use a single data store for all of its needs, since different databases are built for different purposes and not all problems can be elegantly solved by a single database.

Even using specialized relational databases for different purposes, such as data warehousing appliances or analytics appliances within the same application, can be viewed as polyglot persistence.



### 13.3 Service Usage over Direct Data Store Usage

As we move towards multiple data stores in the application, there may be other applications in the enterprise that could benefit from the use of our data stores or the data stored in them. Using our example, the graph data store can serve data to other applications that need to understand, for example, which products are being bought by a certain segment of the customer base.

Instead of each application talking independently to the graph database, we can wrap the graph database into a service so that all relationships between the nodes can be saved in one place and queried by all the applications (Figure 13.4). The data ownership and the APIs provided by the service are more useful than a single application talking to multiple databases.

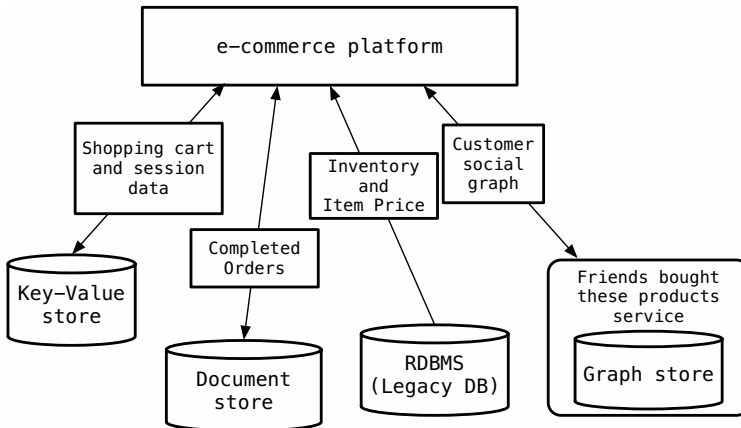


Figure 13.4 Example implementation of wrapping data stores into services

The philosophy of service wrapping can be taken further: You could wrap all databases into services, letting the application to only talk to a bunch of services (Figure 13.5). This allows for the databases inside the services to evolve without you having to change the dependent applications.

Many NoSQL data store products, such as Riak [Riak] and Neo4J [Neo4J], actually provide out-of-the-box REST APIs.

### 13.4 Expanding for Better Functionality

Often, we cannot really change the data storage for a specific usage to something different, because of the existing legacy applications and their dependency on

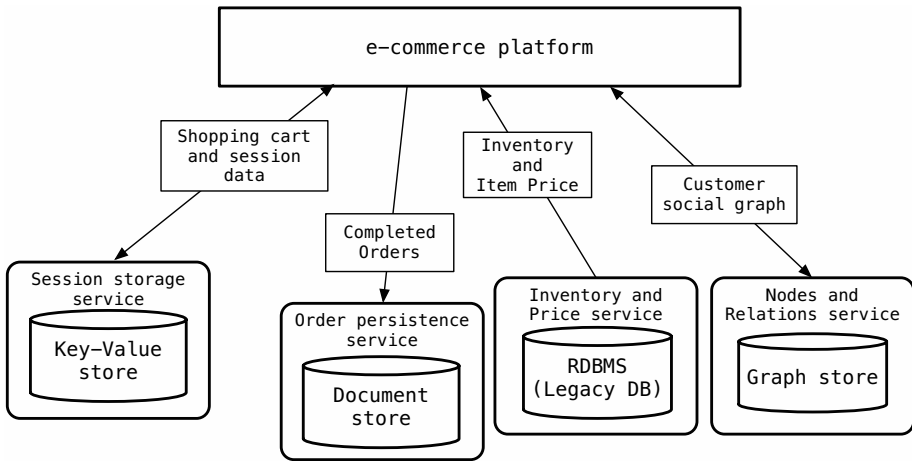


Figure 13.5 Using services instead of talking to databases

existing data storage. We can, however, add functionality such as caching for better performance, or use indexing engines such as Solr [Solr] so that search can be more efficient (Figure 13.6). When technologies like this are introduced, we have to make sure data is synchronized between the data storage for the application and the cache or indexing engine.

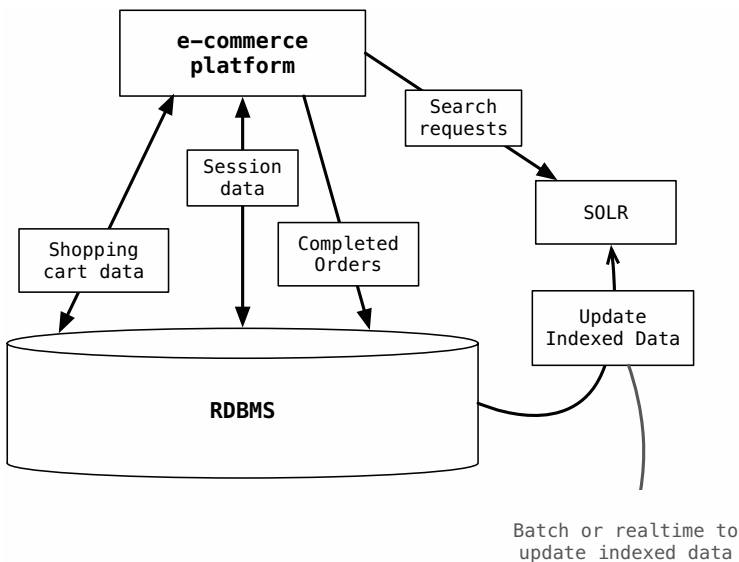


Figure 13.6 Using supplemental storage to enhance legacy storage

While doing this, we need to update the indexed data as the data in the application database changes. The process of updating the data can be real-time or batch, as long as we ensure that the application can deal with stale data in the index/search engine. The event sourcing (“Event Sourcing,” p. 142) pattern can be used to update the index.

---

## 13.5 Choosing the Right Technology

There is a rich choice of data storage solutions. Initially, the pendulum had shifted from speciality databases to a single RDBMS database which allows all types of data models to be stored, although with some abstraction. The trend is now shifting back to using the data storage that supports the implementation of solutions natively.

If we want to recommend products to customers based on what’s in their shopping carts and which other products were bought by customers who bought those products, it can be implemented in any of the data stores by persisting the data with the correct attributes to answer our questions. The trick is to use the right technology, so that when the questions change, they can still be asked with the same data store without losing existing data or changing it into new formats.

Let’s go back to our new feature need. We can use RDBMS to solve this using a hierarchical query and modeling the tables accordingly. When we need to change the traversal, we will have to refactor the database, migrate the data, and start persisting new data. Instead, if we had used a data store that tracks relations between nodes, we could have just programmed the new relations and keep using the same data store with minimal changes.

---

## 13.6 Enterprise Concerns with Polyglot Persistence

Introduction of NoSQL data storage technologies will force the enterprise DBAs to think about how to use the new storage. The enterprise is used to having uniform RDBMS environments; whatever is the database an enterprise starts using first, chances are that over the years all its applications will be built around the same database. In this new world of polyglot persistence, the DBA groups will have to become more poly-skilled—to learn how some of these NoSQL technologies work, how to monitor these systems, back them up, and take data out of and put into these systems.

Once the enterprise decides to use any NoSQL technology, issues such as licensing, support, tools, upgrades, drivers, auditing, and security come up. Many

NoSQL technologies are open-source and have an active community of supporters; also, there are companies that provide commercial support. There is not a rich ecosystem of tools, but the tool vendors and the open-source community are catching up, releasing tools such as MongoDB Monitoring Service [Monitoring], Datastax Ops Center [OpsCenter], or Rekon browser for Riak [Rekon].

One other area that enterprises are concerned about is security of the data—the ability to create users and assign privileges to see or not see data at the database level. Most of the NoSQL databases do not have very robust security features, but that’s because they are designed to operate differently. In traditional RDBMS, data was served by the database and we could get to the database using any query tools. With the NoSQL databases, there are query tools as well but the idea is for the application to own the data and serve it using services. With this approach, the responsibility for the security lies with the application. Having said that, there are NoSQL technologies that introduce security features.

Enterprises often have data warehouse systems, BI, and analytics systems that may need data from the polyglot data sources. Enterprises will have to ensure that the ETL tools or any other mechanism they are using to move data from source systems to the data warehouse can read data from the NoSQL data store. The ETL tool vendors are coming out with the ability to talk to NoSQL databases; for example, Pentaho [Pentaho] can talk to MongoDB and Cassandra.

Every enterprise runs analytics of some sort. As the sheer volume of data that needs to be captured increases, enterprises are struggling to scale their RDBMS systems to write all this data to the databases. A huge number of writes and the need to scale for writes are a great use case for NoSQL databases that allow you to write large volumes of data.

---

## 13.7 Deployment Complexity

Once we start down the path of using polyglot persistence in the application, **deployment complexity** needs careful consideration. The application now needs all databases in production at the same time. You will need to have these databases in your UAT, QA, and Dev environments. As most of the NoSQL products are open-source, there are few license cost ramifications. They also support automation of installation and configuration. For example, to install a database, all that needs to be done is download and unzip the archive, which can be automated using `curl` and `unzip` commands. These products also have sensible defaults and can be started with minimum configuration.

## 13.8 Key Points

- Polyglot persistence is about using different data storage technologies to handle varying data storage needs.
- Polyglot persistence can apply across an enterprise or within a single application.
- Encapsulating data access into services reduces the impact of data storage choices on other parts of a system.
- Adding more data storage technologies increases complexity in programming and operations, so the advantages of a good data storage fit need to be weighed against this complexity.

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# Index

## A

ACID (Atomic, Consistent, Isolated, and Durable) transactions, 19  
in column-family databases, 109  
in graph databases, 28, 50, 114–115  
in relational databases, 10, 26  
vs. BASE, 56

ad banners, 108–109

aggregate-oriented databases, 14, 19–23, 147  
atomic updates in, 50, 61  
disadvantages of, 30  
no ACID transactions in, 50  
performance of, 149  
vs. graph databases, 28

aggregates, 14–23  
changing structure of, 98, 132  
modeling, 31  
real-time analytics with, 33  
updating, 26

agile methods, 123

Amazon, 9  
*See also* DynamoDB, SimpleDB

analytics  
counting website visitors for, 108  
of historic information, 144  
real-time, 33, 98

Apache Pig language, 76

Apache ZooKeeper library, 104, 115

application databases, 7, 146  
updating materialized views in, 31

arcs (graph databases). *See* edges

atomic cross-document operations, 98

atomic rebalancing, 58

atomic transactions, 92, 104

atomic updates, 50, 61

automated failovers, 94

automated merges, 48

automated rollbacks, 145

auto-sharding, 39

availability, 53  
in column-family databases, 104–105  
in document databases, 93  
in graph databases, 115  
vs. consistency, 54  
*See also* CAP theorem

averages, calculating, 72

## B

backward compatibility, 126, 131

BASE (Basically Available, Soft state, Eventual consistency), 56

Berkeley DB, 81

BigTable DB, 9, 21–22

bit-mapped indexes, 106

blogging, 108

Blueprints property graph, 115

Brewer, Eric, 53

Brewer's Conjecture. *See* CAP theorem

buckets (Riak), 82  
default values for consistency for, 84  
domain, 83  
storing all data together in, 82

business transactions, 61

## C

caching  
performance of, 39, 137  
stale data in, 50

Cages library, 104

- CAP (Consistency, Availability, and Partition tolerance) theorem, 53–56
    - for document databases, 93
    - for Riak, 86
  - CAS (compare-and-set) operations, 62
  - Cassandra DB, 10, 21–22, 99–109
    - availability in, 104–105
    - column families in:
      - commands for, 105–106
      - standard, 101
      - super, 101–102
    - columns in, 100
      - expiring, 108–109
      - indexing, 106–107
      - reading, 107
      - super, 101
    - compaction in, 103
    - consistency in, 103–104
    - ETL tools for, 139
    - hinted handoff in, 104
    - keyspaces in, 102–104
    - memtables in, 103
    - queries in, 105–107
    - repairs in, 103–104
    - replication factor in, 103
    - scaling in, 107
    - SSTables in, 103
    - timestamps in, 100
    - transactions in, 104
      - wide/skinny rows in, 23
  - clients, processing on, 67
  - Clojure language, 145
  - cloud computing, 149
  - clumping, 39
  - clusters, 8–10, 67–72, 76, 149
    - in file systems, 8
    - in Riak, 87
    - resiliency of, 8
  - column-family databases, 21–23, 99–109
    - ACID transactions in, 109
    - columns for materialized views in, 31
    - combining peer-to-peer replication and sharding in, 43–44
    - consistency in, 103–104
    - modeling for, 34
    - performance in, 103
    - schemalessness of, 28
    - vs. key-value databases, 21
    - wide/skinny rows in, 23
  - combinable reducers, 70–71
  - compaction (Cassandra), 103
  - compatibility, backward, 126, 131
  - concurrency, 145
    - in file systems, 141
    - in relational databases, 4
    - offline, 62
  - conditional updates, 48, 62–63
  - conflicts
    - key, 82
    - read-write, 49–50
    - resolving, 64
    - write-write, 47–48, 64
  - consistency, 47–59
    - eventual, 50, 84
    - in column-family databases, 103–104
    - in graph databases, 114
    - in master-slave replication, 52
    - in MongoDB, 91
    - logical, 50
    - optimistic/pessimistic, 48
    - read, 49–52, 56
    - read-your-writes, 52
    - relaxing, 52–56
    - replication, 50
    - session, 52, 63
    - trading off, 57
    - update, 47, 56, 61
    - vs. availability, 54
    - write, 92
    - See also* CAP theorem
  - content hashes, 62–63
  - content management systems, 98, 108
  - CouchDB, 10, 91
    - conditional updates in, 63
    - replica sets in, 94
  - counters, for version stamps, 62–63
  - CQL (Cassandra Query Language), 10, 106
  - CQRS (Command Query Responsibility Segregation), 143
  - cross-document operations, 98
  - C-Store DB, 21
  - Cypher language, 115–119
- ## D
- Data Mapper and Repository pattern, 151
  - data models, 13, 25
    - aggregate-oriented, 14–23, 30
    - document, 20
    - key-value, 20
    - relational, 13–14



data redundancy, 94

databases

- choosing, 7, 147–152
- deploying, 139
- encapsulating in explicit layer, 151
- NoSQL, definition of, 10–11
- shared integration of, 4, 6

Datastax Ops Center, 139

DBDeploy framework, 125

DBMaintain tool, 126

deadlocks, 48

demo access, 108

Dependency Network pattern, 77

deployment complexity, 139

Dijkstra’s algorithm, 118

disaster recovery, 94

distributed file systems, 76, 141

distributed version control systems, 48

- version stamps in, 64

distribution models, 37–43

- See also* replications, sharding, single server approach

document databases, 20, 23, 89–98

- availability in, 93
- embedding child documents into, 90
- indexes in, 25
- master-slave replication in, 93
- performance in, 91
- queries in, 25, 94–95
- replica sets in, 94
- scaling in, 95
- schemalessness of, 28, 98
- XML support in, 146

domain buckets (Riak), 83

Domain-Driven Design, 14

DTDs (Document Type Definitions), 146

durability, 56–57

DynamoDB, 9, 81, 100

- shopping carts in, 55

Dynomite DB, 10

## E

early prototypes, 109

e-commerce

- data modeling for, 14
- flexible schemas for, 98
- polyglot persistence of, 133–138
- shopping carts in, 55, 85, 87

edges (graph databases), 26, 111

eligibility rules, 26

## enterprises

- commercial support of NoSQL for, 138–139
- concurrency in, 4
- DB as backing store for, 4
- event logging in, 97
- integration in, 4
- polyglot persistence in, 138–139
- security of data in, 139

error handling, 4, 145

etags, 62

ETL tools, 139

Evans, Eric, 10

event logging, 97, 107–108

event sourcing, 138, 142, 144

eventual consistency, 50

- in Riak, 84

expiring usage, 108–109

## F

failovers, automated, 94

file systems, 141

- as backing store for RDBMS, 3
- cluster-aware, 8
- concurrency in, 141
- distributed, 76, 141
- performance of, 141
- queries in, 141

FlockDB, 113

- data model of, 27
- node distribution in, 115

## G

Gilbert, Seth, 53

Google, 9

- Google BigTable. *See* BigTable
- Google File System, 141

graph databases, 26–28, 111–121, 148

- ACID transactions in, 28, 50, 114–115
- aggregate-ignorance of, 19
- availability in, 115
- consistency in, 114
- creating, 113
- edges (arcs) in, 26, 111
- held entirely in memory, 119
- master-slave replication in, 115
- migrations in, 131
- modeling for, 35
- nodes in, 26, 111–117
- performance of, 149

graph databases (*continued*)  
 properties in, 111  
 queries in, 115–119  
 relationships in, 111–121  
 scaling in, 119  
 schemalessness of, 28  
 single server configuration of, 38  
 traversing, 111–117  
 vs. aggregate databases, 28  
 vs. relational databases, 27, 112  
 wrapping into service, 136  
 Gremlin language, 115  
 GUID (Globally Unique Identifier), 62

## H

Hadoop project, 67, 76, 141  
 HamsterDB, 81  
 hash tables, 62–63, 81  
 HBase DB, 10, 21–22, 99–100  
 Hector client, 105  
 Hibernate framework, 5, 147  
 hinted handoff, 104  
 hive DB, 76  
 hot backup, 40, 42  
 hotel booking, 4, 55  
 HTTP (Hypertext Transfer Protocol), 7  
 interfaces based on, 85  
 updating with, 62  
 Hypertable DB, 10, 99–100

## I

iBATIS, 5, 147  
 impedance mismatch, 5, 12  
 inconsistency  
 in shopping carts, 55  
 of reads, 49  
 of updates, 56  
 window of, 50–51, 56  
 indexes  
 bit-mapped, 106  
 in document databases, 25  
 stale data in, 138  
 updating, 138  
 Infinite Graph DB, 113  
 data model of, 27  
 node distribution in, 114–115  
 initial tech spikes, 109  
 integration databases, 6, 11  
 interoperability, 7

## J

JSON (JavaScript Object Notation), 7,  
 94–95, 146

## K

keys (key-value databases)  
 composite, 74  
 conflicts of, 82  
 designing, 85  
 expiring, 85  
 grouping into partitions, 70  
 keyspaces (Cassandra), 102–104  
 key-value databases, 20, 23, 81–88  
 consistency of, 83–84  
 modeling for, 31–33  
 no multiple key operations in, 88  
 schemalessness of, 28  
 sharding in, 86  
 structure of values in, 86  
 transactions in, 84, 88  
 vs. column-family databases, 21  
 XML support in, 146

## L

Liquibase tool, 126  
 location-based services, 120  
 locks  
 dead, 48  
 offline, 52  
 lost updates, 47  
 Lotus DB, 91  
 Lucene library, 85, 88, 116  
 Lynch, Nancy, 53

## M

MapReduce framework, 67  
 map-reduce pattern, 67–77  
 calculations with, 72  
 incremental, 31, 76–77  
 maps in, 68  
 materialized views in, 76  
 partitions in, 70  
 reusing intermediate outputs in, 76  
 stages for, 73–76  
 master-slave replication, 40–42  
 appointing masters in, 41, 57  
 combining with sharding, 43  
 consistency of, 52  
 in document databases, 93

- in graph databases, 115
- version stamps in, 63
- materialized views, 30
  - in map-reduce, 76
  - updating, 31
- Memcached DB, 81, 87
- memory images, 144–145
- memtables (Cassandra), 103
- merges, automated, 48
- migrations, 123–132
  - during development, 124, 126
  - in graph databases, 131
  - in legacy projects, 126–128
  - in object-oriented databases, 146
  - in schemaless databases, 128–132
  - incremental, 130
  - transition phase of, 126–128
- mobile apps, 131
- MongoDB, 10, 91–97
  - collections in, 91
  - consistency in, 91
  - databases in, 91
  - ETL tools for, 139
  - queries in, 94–95
  - replica sets in, 91, 93, 96
  - schema migrations in, 128–131
  - sharding in, 96
  - slaveOk parameter in, 91–92, 96
  - terminology in, 89
  - writeConcern parameter in, 92
- MongoDB Monitoring Service, 139
- MyBatis Migrator tool, 126
- MySQL DB, 53, 119

## N

- Neo4J DB, 113–118
  - ACID transactions in, 114–115
  - availability in, 115
  - creating graphs in, 113
  - data model of, 27
  - replicated slaves in, 115
  - service wrapping in, 136
- nodes (graph databases), 26, 111
  - distributed storage for, 114
  - finding paths between, 117
  - indexing properties of, 115–116
- nonuniform data, 10, 28, 30
- NoSQL databases
  - advantages of, 12
  - definition of, 10–11

- lack of support for transactions in,
  - 10, 61
- running of clusters, 10
- schemalessness of, 10

## O

- object-oriented databases, 5, 146
  - migrations in, 146
  - vs. relational databases, 6
- offline concurrency, 62
- offline locks, 52
- Optimistic Offline Lock, 62
- Oracle DB
  - redo log in, 104
  - terminology in, 81, 89
- Oracle RAC Server, 8
- OrientDB, 91, 113
- ORM (Object-Relational Mapping)
  - frameworks, 5–6, 147
- Oskarsson, Johan, 9

## P

- partition tolerance, 53–54
  - See also* CAP theorem
- partitioning, 69–70
- peer-to-peer replication, 42–43
  - durability of, 58
  - inconsistency of, 43
  - version stamps in, 63–64
- Pentaho tool, 139
- performance
  - and sharding, 39
  - and transactions, 53
  - binary protocols for, 7
  - caching for, 39, 137
  - data-access, 149–150
  - in aggregate-oriented databases, 149
  - in column-family databases, 103
  - in document databases, 91
  - in graph databases, 149
  - responsiveness of, 48
  - tests for, 149
- pipes-and-filters approach, 73
- polyglot persistence, 11, 133–139, 148
  - and deployment complexity, 139
  - in enterprises, 138–139
- polyglot programming, 133–134
- processing, on clients/servers, 67
- programmer productivity, 147–149
- purchase orders, 25

## Q

## queries

- against varying aggregate structure, 98
  - by data, 88, 94
  - by key, 84–86
  - for files, 141
  - in column-family databases, 105–107
  - in document databases, 25, 94–95
  - in graph databases, 115–119
  - precomputed and cached, 31
  - via views, 94
- quorums, 57, 59
- read, 58
  - write, 58, 84

## R

Rails Active Record framework, 147

RavenDB, 91

- atomic cross-document operations in, 98
- replica sets in, 94
- transactions in, 92

RDBMS. *See* relational databases

## reads

- consistency of, 49–52, 56, 58
- horizontal scaling for, 94, 96
- inconsistent, 49
- multiple nodes for, 143
- performance of, 52
- quorums of, 58
- repairs of, 103
- resilience of, 40–41
- separating from writes, 41
- stale, 56

read-write conflicts, 49–50

read-your-writes consistency, 52

Real Time Analytics, 33

Real Time BI, 33

rebalancing, atomic, 58

recommendation engines, 26, 35, 121, 138

Redis DB, 81–83

redo log, 104

reduce functions, 69

- combinable, 70–71

regions. *See* map-reduce pattern, partitions  
in

Rekon browser for Riak, 139

relational databases (RDBMS), 13, 17

- advantages of, 3–5, 7–8, 150
- aggregate-ignorance of, 19
- backing store in, 3
- clustered, 8

columns in, 13, 90

concurrency in, 4

defining schemas for, 28

impedance mismatch in, 5, 12

licensing costs of, 8

main memory in, 3

modifying multiple records at once in, 26

partitions in, 96

persistence in, 3

relations (tables) in, 5, 13

schemas for, 29–30, 123–128

security in, 7

sharding in, 8

simplicity of relationships in, 112

strong consistency of, 47

terminology in, 81, 89

transactions in, 4, 26, 92

tuples (rows) in, 5, 13–14

views in, 30

vs. graph databases, 27, 112

vs. object-oriented databases, 6

XML support in, 146

relationships, 25, 111–121

dangling, 114

direction of, 113, 116, 118

in RDBMS, 112

properties of, 113–115

traversing, 111–117

RelaxNG, 146

replica sets, 91, 93, 96

replication factor, 58

in column-family databases, 103

in Riak, 84

replications, 37

combining with sharding, 43

consistency of, 42, 50

durability of, 57

over clusters, 149

performance of, 39

version stamps in, 63–64

*See also* master-slave replication,  
peer-to-peer replication

resilience

and sharding, 39

read, 40–41

responsiveness, 48

Riak DB, 81–83

clusters in, 87

controlling CAP in, 86

eventual consistency in, 84

HTTP-based interface of, 85

- link-walking in, 25
- partial retrieval in, 25
- replication factor in, 84
- service wrapping in, 136
- terminology in, 81
- transactions in, 84
- write tolerance of, 84
- Riak Search, 85, 88
- rich domain model, 113
- rollbacks, automated, 145
- routing, 120
- rows (RDBMS). *See* tuples

**S**

- scaffolding code, 126
- scaling, 95
  - horizontal, 149
    - for reads, 94, 96
    - for writes, 96
  - in column-family databases, 107
  - in document databases, 95
  - in graph databases, 119
  - vertical, 8
- Scatter-Gather pattern, 67
- schemaless databases, 28–30, 148
  - implicit schema of, 29
  - schema changes in, 128–132
- schemas
  - backward compatibility of, 126, 131
  - changing, 128–132
  - during development, 124, 126
  - implicit, 29
  - migrations of, 123–132
- search engines, 138
- security, 139
- servers
  - maintenance of, 94
  - processing on, 67
- service-oriented architecture, 7
- services, 136
  - and security, 139
  - decomposing database layer into, 151
  - decoupling between databases and, 7
  - over HTTP, 7
- sessions
  - affinity, 52
  - consistency of, 52, 63
  - expire keys for, 85
  - management of, 133
  - sticky, 52
  - storing, 57, 87

- sharding, 37–38, 40, 149
  - and performance, 39
  - and resilience, 39
  - auto, 39
  - by customer location, 97
  - combining with replication, 43
  - in key-value databases, 86
  - in MongoDB, 96
  - in relational databases, 8
- shared database integration, 4, 6
- shopping carts
  - expire keys for, 85
  - inconsistency in, 55
  - persistence of, 133
  - storing, 87
- shuffling, 70
- SimpleDB, 99
  - inconsistency window of, 50
- single server approach, 37–38
  - consistency of, 53
  - no partition tolerance in, 54
  - transactions in, 53
  - version stamps in, 63
- single-threaded event processors, 145
- snapshots, 142–143
- social networks, 26, 120
  - relationships between nodes in, 117
- Solr indexing engine, 88, 137, 141
- split brain situation, 53
- SQL (Structured Query Language), 5
- SSTables (Cassandra), 103
- stale data
  - in cache, 50
  - in indexes/search engines, 138
  - reading, 56
- standard column families (Cassandra), 101
- sticky sessions, 52
- storage models, 13
- Strozzi, Carlo, 9
- super column families (Cassandra), 101–102
- super columns (Cassandra), 101
- system transactions, 61

**T**

- tables. *See* relational databases, relations in
- telemetric data from physical devices, 57
- Terrastore DB, 91, 94
- timestamps
  - consistent notion of time for, 64
  - in column-family databases, 100
  - of last update, 63

transactional memory systems, 145  
 transactions, 50  
   ACID, 10, 19, 26, 28, 50, 56, 109,  
   114–115  
   across multiple operations, 92  
   and performance, 53  
   atomic, 92, 104  
   business, 61  
   in graph databases, 28, 114–115  
   in key-value databases, 84, 88  
   in RDBMS, 4, 26, 92  
   in single server systems, 53  
   lack of support in NoSQL for, 10, 61  
   multioperation, 88  
   open during user interaction, 52  
   rolling back, 4  
   system, 61  
 tree structures, 117  
 triggers, 126  
 TTL (Time To Live), 108–109  
 tuples (RDBMS), 5, 13–14

## U

updates  
   atomic, 50, 61  
   conditional, 48, 62–63  
   consistency of, 47, 56, 61  
   lost, 47  
   merging, 48  
   timestamps of, 63–64  
 user comments, 98  
 user preferences, 87  
 user profiles, 87, 98  
 user registrations, 98  
 user sessions, 57

## V

vector clock, 64  
 version control systems, 126, 145  
   distributed, 48, 64

version stamps, 52, 61–64  
 version vector, 64  
 views, 126  
 virtual columns, 126  
 Voldemort DB, 10, 82

## W

web services, 7  
 websites  
   distributing pages for, 39  
   on large clusters, 149  
   publishing, 98  
   visitor counters for, 108  
 word processors, 3  
 write tolerance, 84  
 writes, 64  
   atomic, 104  
   conflicts of, 47–48  
   consistency of, 92  
   horizontal scaling for, 96  
   performance of, 91  
   quorums of, 58  
   separating from reads, 41  
   serializing, 47

## X

XML (Extensible Markup Language), 7, 146  
 XML databases, 145–146  
 XML Schema language, 146  
 XPath language, 146  
 XQuery language, 146  
 XSLT (Extensible Stylesheet Language  
   Transformations), 146

## Z

ZooKeeper. *See* Apache ZooKeeper