Pramod J. Sadalage | Martin Fowler

NoSQL

A Brief Guide to the Emerging World of Polyglot Persistence

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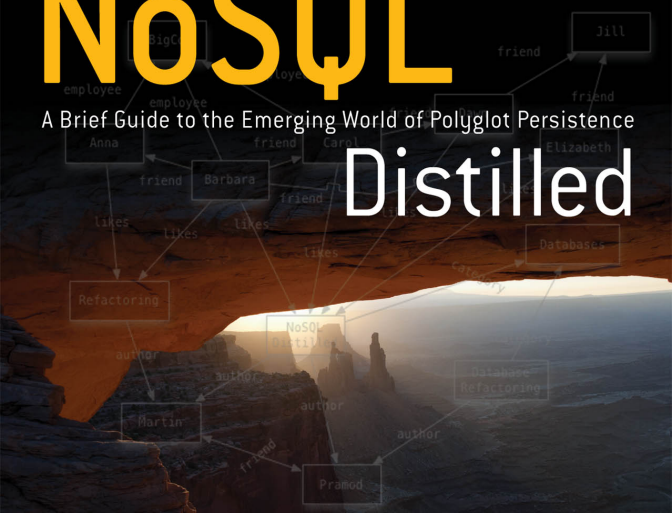

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A Brief Guide to the Emerging World of Polyglot Persistence

Pramod J. Sadalage
Martin Fowler

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—Pramod

For Cindy

—Martin

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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.

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.

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
	Riak
Document ("Document Databases," p. 89)	CouchDB
	MongoDB
	OrientDB
	RavenDB
	Terrastore
Column-Family ("Column-Family Stores," p. 99)	Amazon SimpleDB
	Cassandra
	HBase
	Hypertable
Graph ("Graph Databases," p. 111)	FlockDB
	HyperGraphDB
	Infinite Graph
	Neo4J
	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.

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 Rodriquez, 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

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.

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

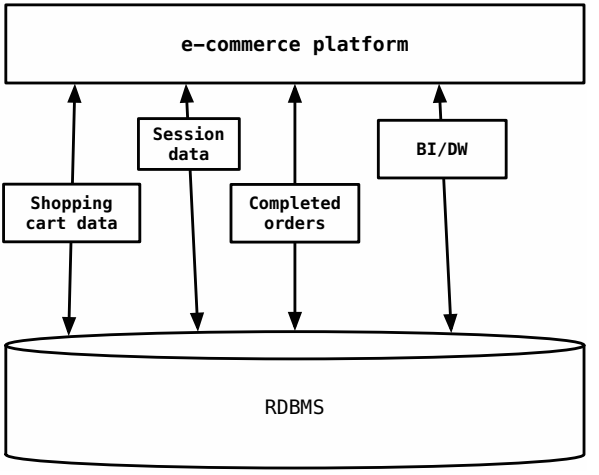

Figure 13.1 *Use of RDBMS for every aspect of storage for the application*

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.

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"

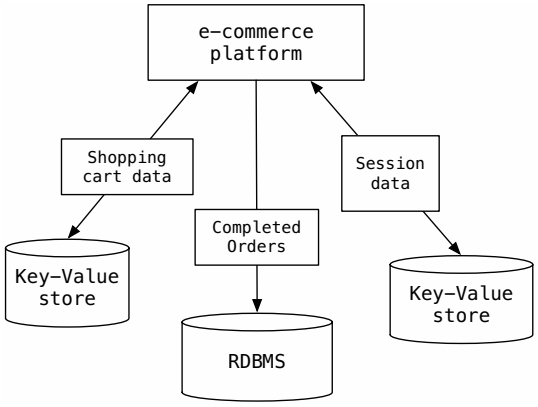

Figure 13.2 *Use of key-value stores to offload session and shopping cart data storage*

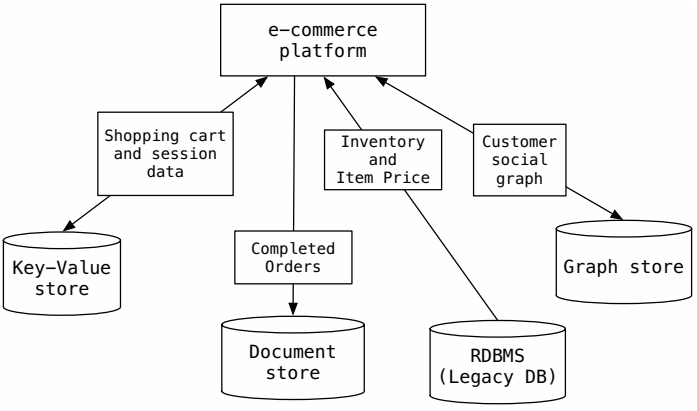

Figure 13.3 *Example implementation of polyglot persistence*

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 singe 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.

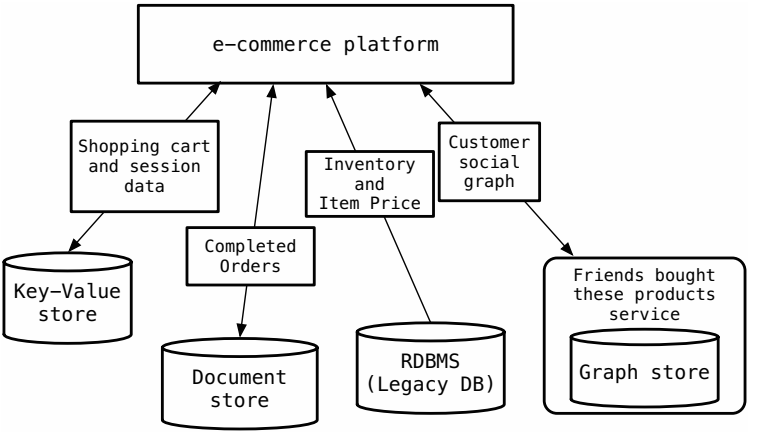

Figure 13.4 *Example implementation of wrapping data stores into services*

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 API's.

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

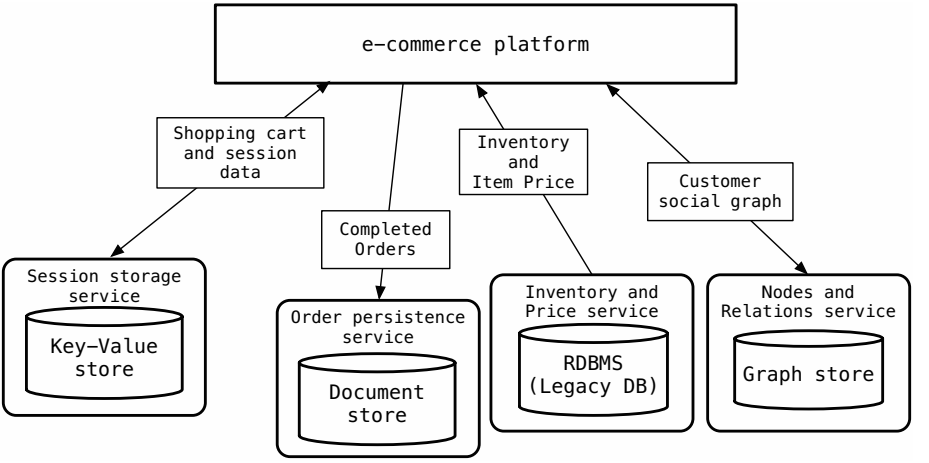

Figure 13.5 *Using services instead of talking to databases*

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.

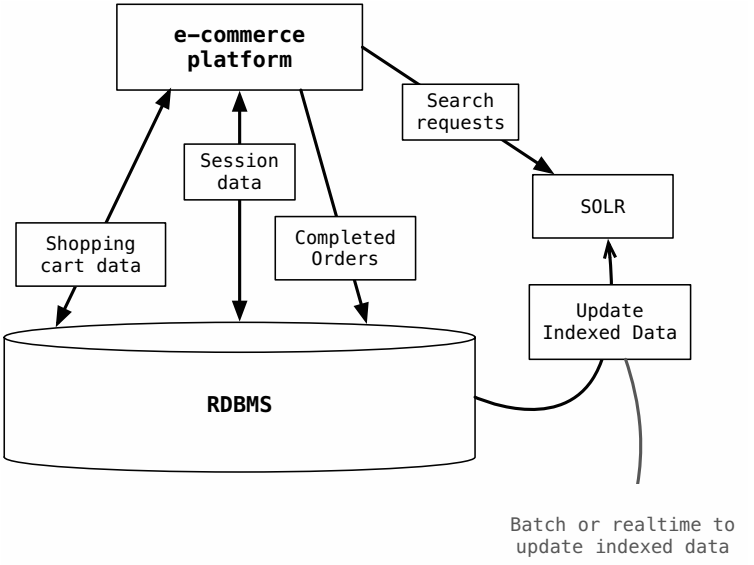

Figure 13.6 *Using supplemental storage to enhance legacy storage*

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 hierarchal 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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