Оценка на NoSQL бази данни за внедряване на цифрови финансови услуги

М. Ковачева

Evaluation of NoSQL Databases for Digital Financial Services Implementation

M. Kovacheva

Department of Information Technology and Communications, University of National and World Economy, Student District, 19, December 8th St., 1700 Sofia, Bulgaria, mkovacheva@unwe.bg

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Abstract. *Digital transformation covers different processes and one of the most important industries that has been developing and becoming increasingly digitized in the last years is banking and financial services. For the banks to meet their customers' demands, needs and expectations it is important to make changes and adapt quickly to the developing technologies. In addition to that, banks need to manage great volumes of data while making changes to their systems without causing data losses and problems for their customers. Financial services provided by banks, credit unions, accountant companies, insurance companies, investment funds, stock brokerages, etc. need databases that can adapt to the increasing need for automation for which NoSQL databases can be very useful. Non-relational databases handle big amounts of data, they are scalable and deliver better performance when processing data. This study presents specifications for NoSQL databases and evaluation approach for non-relational database for financial services.*

1. Introduction

Technologies are developing at an extremely fast pace and digitalization covers more and more processes with which the data which is generated and collected increases every day. This is the reason why new ways for storing data are created. Traditional ways as relational databases cannot cope with the evolving needs of technology [25,29]. They are not suitable for every situation as they cannot be used to store and process unstructured data, for this reason non-relational databases appeared. NoSQL started as databases for giants like Facebook, Google, Amazon, Twitter, etc. which needed scaling and fast performance with the big volumes of data that are generated every minute, but they expanded quickly in other spheres. Digital transformation is the main aim not only for the banks, but for all institutions that offer financial services. This transformation was accelerated by the pandemic in 2020 and there was need of regular processes to become digital very fast. Nowadays, many companies are adopting the usage of non-relational databases because they are scalable, flexible, and schema-less which helps to provide ways of storing unpredictable data. The information presently comes from different sources and in different types, in which the SQL databases are becoming less and less productive, and even in some cases useless. The main aim of this paper is to show the specifications of NoSQL databases and to display that non-relational databases can be used in different financial services. The biggest challenge for the services in the financial sphere is to shift from legacy systems, which were used in the past to modern ones using new technologies [1].

2. Specifications of NoSQL Databases

Financial institutions are competing in between each other, which one will be able to digitalize its processes faster and, in this way, will be more responsive to the needs of the customers. Instead of storing data into tables with columns and rows, NoSQL databases offer storing and accessing with key-values. Non-relational databases do not need predefined schema and are able to store different types of data as structured, semi-structured and unstructured collected from different sources [2].

NoSQL databases offer better performance, better horizontal scaling as data grows, faster and easier implementation compared to traditional SQL. There are four types of NoSQL: document-based, key-value stores, column-oriented and graph-based databases – *Figure 1*.

Figure 1. Types of NoSQL databases

Document-based databases use documents to store the data, which can be JSON, BSON or XML. These types of databases are distributed which allows horizontal scaling when it's needed. Also, they have flexible schema, which allows changes to the data model when the application requires it [3,28].

Key-value stores database it is the simplest of the NoSQL databases and stores the data into collections of key-value pairs as the key is the unique identifier. The main features of this non-relational database are that is simple, scalable, and a very fast NoSQL database [4,28].

Column-oriented database stores data in columns and not in rows as the relational databases do. This type of database can read data more efficiently and retrieve it very fast. The main features of this database are that is scalable, responsive, fast and allows compression [5,28].

Graph database stores data in nodes, has edges and attributes. The nodes are connected to related data via the edges. The connection between nodes is a relationship. Graph database is without predefined schema, which allows great flexibility for the applications that are developed [6,28].

The need for digitalization of financial services processes is enormous. NoSQL databases offer not only flexibility for the applications that are developed, but scalability at a lower cost, something that relational databases cannot do. The necessity of real-time processing and analytics of data for authentication, authorization, fraud detection for financial services leads to the need for NoSQL databases. Some of the benefits from using NoSQL databases in financial services are as follows:

- **Improved fraud prevention and crime monitoring in the financial sphere.** That is one of the biggest advantages of NoSQL and the real-time analytics that can be made. This is important in the financial services – banks, credit, and debit cards, etc. All these institutions are working with extremely sensitive information which is crucial for understanding and satisfaction of clients. Fraud in the financial services is increasing which can be prevented with the usage of analytics, identification of anomalies, classification, and clustering, which can be achieved with NoSQL databases [1,30]. Fraud prevention and crime monitoring are of extreme importance to protect customer personal information and their sensitive information, also their online transactions and data.
- **Real-time digital authorization.** This functionality is exceedingly important for the financial services and to make sure that fraud won't happen, and for people to be able to identify the person they are contacting with. NoSQL databases are capable of this because of the reduced read latency and the verification could happen almost instantly [1,31]. Real-time digital authorization is directly connected to fraud prevention, and in this way is again with highest priority when we are talking about financial services and required to be realized when making online transactions.
- **Personalized offerings.** For clients is exceptionally important to have personalized offerings especially for their needs. In the financial services there is no difference – insurance policies based on personal risk, interest rates based on repayment and capacity, etc. For these personalized offerings to happen there is need of information to be gathered – behaviors, social media engagement, cookies, online shopping, etc. and all this data is coming from different sources for which NoSQL databases come in hand. This type of database will help with the fast real-time analytics and for the customers to be provided with proper personalized offers. With developing technologies, NoSQL databases become more widely used and more profitable because they are scaling horizontally [1,32]. In the digital era that we live in it's of utmost importance for the users to receive personalized offerings not only for the common necessities that they are buying, but for all the financial services that are offered on the market. The reason for that is that there are many products offered from different banks, insurance companies, etc. and based on the information gathered and analyzed for the clients, the best product can be offered.
- **Pre-trade assistance.** Studies show the information gathered from different resources as the data could be in structured and unstructured format, and in this way risk assessment can be made and trade decisions could be taken. This could be done because the data is studied in real time. Another important thing is that traders can be alerted when there are changes in the markets. This is very important for trading because if the right decision is not made, a lot of money could be lost [1,30]. Pre-trade assistance is directly connected to the personalized offerings also defined as a benefit. The information gathered for the client when it is properly analyzed will give the company the best competitive advantage as to offer the ideal financial product to the client.
- **Targeted marketing.** This benefit of the NoSQL databases in the financial services is partially connected with the personalization discussed in the previous points. Information and data for searching, buying, and selling is used to make real-time analysis and to offer the clients advertisements for the right product that they will be interested in [1,33]. Targeted marketing is also of great importance when talking for financial services, because when analyzed properly can give the companies perfect knowledge what are the needs, demands and expectations of the client, and what is perfect product to offer and later there is greater chance to end up as a sale.

3. Essence of the Evaluation of NoSQL Databases for Digital Financial Services

Every type of NoSQL database has its advantages and disadvantages for specific situations. In this point we are going to look at a couple of examples from every non-relational database, and more specifically for which financial services they can be used.

Old technologies are not only slowing down the financial institution, but they are expensive to maintain, and this is one of main reasons legacy systems need to be migrated to new databases. In the following paragraphs we will look more in depth at some examples from every type of NoSQL database. The ones that will be considered are chosen after detailed research which non-relational DBs support different financial services.

We will start with the **Document-oriented** ones and the examples that we will look at are Couchbase and MongoDB in use for financial services. **Couchbase** offers multi-dimensional scaling, which means that the database can be easily scaled while using it. In this way the performance of the app is increased, and the cost is reduced. The multi-dimensional scaling separates, isolates and scales the services of the database – index, query, and data. This is a way in which every resource can be optimized without any of the performance suffering [7]. Real-time analytics is very fast when run on Couchbase, which is important for fraud detection, trade analytics, etc. Couchbase is used by FICO for fraud detection; Apple, Android and Samsung pay tokens/mobile wallets/ are based on it. For the e-payments PayPal uses Couchbase to manage over 1 billion documents and terabytes of data, and to process them every minute. Big investment banks are using Couchbase to gather data from different sources and to provide it. Also, it can be used for improving trade, as a lot of data for current markets and historical prices can be handled and analyzed fast [8].

MongoDB is schema-less, provides high performance, supports MapReduce and aggregations tools, horizontal scalability, and built-in replication. Also supports connection to Hadoop with special connector. MongoDB offers real-time analytics which can gather data from multiple sources, as this can help you analyze the clients' demands and needs [9]. Royal Bank of Scotland adopted MongoDB in several of their core trading systems. AHL, a quantitative investment firm, relies fully on MongoDB, because of the low frequency data. This non-relational database retrieves the data 100 times faster and delivers steady retrieval times, which made cost savings for the firm. MongoDB captures all the market activity of the company and scales very quickly when needed [10].

The next type of database that we will look at is the **Key-value pair** and the examples that we will look at are Amazon DynamoDB and Redis in use for financial services. **Amazon DynamoDB** performs at scale and can support a lot of data with horizontal scaling, it has flexible schema which allows easy adaptation when the requirements of the app change. AWS also offers automatic replications and scaling [11]. On this database are based banking institutions, capital markets, etc. For example, Robinhood is a trading app which uses Amazon DynamoDB to securely store its customers information and trading data, and to perform business analytics [12]. Many digital banks are basing their systems on Amazon DynamoDB because the platform is scalable, secure, and innovative. Some examples are Starling Bank, Judo Bank, Monzo, etc. [13].

Redis offers an in-memory datastore, which gives an opportunity to get faster responses from the system and supports millions of operations. This non-relational database has high availability and scalability and can be scaled horizontally and vertically. Redis is data persistent, which means that the data should last even when there is a failure with the server and offers great variety of data structures which gives opportunity to the developers to choose the best option for their app [14]. As many of the social medias use Redis as their database, nowadays many financial institutions are adopting it too. One of the companies in the financial services using Redis is Ekata, which is a company for identity verification and fraud prevention for payments, ecommerce, and financial services industries [15].

The next type of database that we will look at is **Column-oriented** ones. The examples that will be taken into consideration are **MariaDB**, HBase and Cassandra. Starting with MariaDB, it has great data integrity which means it can be globally scaled without sacrificing its ACID principles. This NoSQL database offers continuous availability – it can tolerate failures because of its good multi-site replication. It has Kafka and Spark connectors, and it's capable of direct data loading into storage from anywhere [16]. MariaDB is used for high volume transactions across multiple regions, which is a key functionality for banking, card processing, trading, etc. Also, it is used for fraud detection, identity theft, money, and account takeover. Another important thing that MariaDB is used for is customer experience – to provide the best offer for the customers based on their previous choices. An example of a financial institution which adopted MariaDB is Financial Network, Inc. This is a company that is building custom loan software, reports and automating credit decisions [17].

HBase is a part of the Hadoop ecosystem. In this type of database, the data can be stored in Hadoop as the most important features are that is scalable, has failure support(automatic), integrates with Hadoop, and provides data replication across clusters [18]. Except for the social media that use HBase, there companies which have adapted the database to their financial services. An example of that is Celer Technologies, which is a company that stores financial data for trading and risk [19].

The main features of **Cassandra** are that it is highly scalable, it's distributed and there is great fault-tolerance, because the data is automatically stored and replicated. Cassandra supports MapReduce, as also Apache hive and Apache Pig [20]. The main things in the financial sphere that Cassandra is used for are personalization, recommendation, fraud detection and authentication. One of the biggest

examples in the financial industry is ACI Worldwide, which is a real-time payments software for banks, merchants, and bills pay. The database is horizontally scalable, and more nodes are added to the cluster when the company needs it [21].

The last type of NoSQL database is the **Graph based** ones. The examples covered in this study are Neo4j and Orient DB. **Neo4j** has a flexible schema, as uses a graph model. This model contains nodes which are connected to each other [22]. The three biggest examples using Neo4j in the financial services are UBS, CITI, and Global 50 Bank. UBS is an investment bank and financial services company that turned over to Neo4j to resolve their data lineage challenges. CITI is a banking subsidiary which changes to Neo4j and now the database supports the full range of banking operations, security requirements, and demanding party-related data [23].

The main feature of **Orient DB** is the speed, as this NoSQL database was created to store up to 120,000 records per second. It is flexible, it can run on any platform without configurations and installation. Orient DB has elastic linear scalability and incremental backups. An example for a company using Orient DB is 99Bill, which is a company that provides online payment service and wants to increase not only their speed when working with data but also fraud detection [24].

After a thorough literature review of publications connected to NoSQL and more specifically about the usage of financial services based on non-relational databases [8,10,12,13,15,17,19,21,23,24], a specific way of how to choose which NoSQL database is suitable for given financial service was not detected. There are many websites and companies which offer comparison of different characteristics of the databases [26,27] but in general not for a specific sphere or service.

Based on the research made and the benefits derived and shown in the previous point, we will define them as criteria for evaluating non-relational databases for financial services. The table below is created as an expert appraisal based on literature and studies done on already existing solutions for services in the financial sphere based on NoSQL databases. The criteria are as follows: **security, real-time digital authorization, personalization, pre-trade assistance and targeted marketing,** as each one of them is rated on a scale from 1 to 5. The list of criteria chosen is not exhausted, so more can be added depending on the needs and demands of the clients/company. Depending on the financial service which is evaluated every criterion has a different weight. For example, for services which are directly related to online payments, client profiles with sensitive information, debit and credit card information, core banking systems, insurances, authorization the most important criteria and with highest weight when evaluating are security and real-time digital authorization, because this will prevent frauds.

To evaluate the NoSQL databases, we need to examine two elements. In the first place, if there is a non-relational solution for financial service: **0 – means no solution, 1 – development, 2 – there is fully working financial service solution.** The scale from 0-2 is used, because if there is no solution the weight of the criteria shouldn't it be used, if it's in development the weight it's only 1 and if there is fully working solution the weight of the criteria should be 2. The second element needed for the evaluation is the criteria defined earlier as each one of them has its own weight: **1 – Poor, 2 – Unsatisfactory, 3 – Good, 4 – Very Good and 5 – Excellent.** Every criterion is evaluated on this scale, based on the expert appraisal and literature reviewed for the importance of each one of them and the corresponding financial service. In the end we have calculated the complex value for each financial service and below the total value for each database, which shows the NoSQL databases with the most reliable financial service solutions according to the expert evaluation made.

Evaluation of NoSQL databases for financial services

–			Document-oriented				Key-value pair				Column-oriented						Graph based			
			Couchbase		MongoDB		Amazon DynamoDB		Redis		MariaDB		Hbase		Cassandra		Neo4j		OrientDB	
Financial service (FS)	Criteria	Criteria value	Existing solution?	Complex value	Existing solution?	Complex value	Existing solution?	Complex value	Existing solution?	Complex value	Existing solution?	Complex value	Existing solution?	Complex value	Existing solution?	Complex value	Existing solution?	Complex value	Existing solution?	Complex value
Fraud detection	Security	5	2	**10**	0	**0**	2	**10**	0	**0**	2	**10**	0	**0**	2	**10**	2	**10**	2	**10**
	Real-time DA	5		**10**		**0**		**10**		**0**		**10**		**0**		**10**		**10**		**10**
	Personalization	3		**6**		**0**		**6**		**0**		**6**		**0**		**6**		**6**		**6**
	Pre-trade assistance	2		**4**		**0**		**4**		**0**		**4**		**0**		**4**		**4**		**4**
	Targeted marketing	1		**2**		**0**		**2**		**0**		**2**		**0**		**2**		**2**		**2**
Mobile wallet	Security	5	2	**10**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**
	Real-time DA	5		**10**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
	Personalization	4		**8**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
	Pre-trade assistance	2		**4**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
	Targeted marketing	1		**2**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**

E-payments	Security	5	2	**10**	2	**10**	2	**10**	2	**10**	2	**10**	0	**0**	2	**10**	0	**0**	0	**0**
	Real-time DA	5		**10**		**10**		**10**		**10**		**10**		**0**		**10**		**0**		**0**
	Personalization	2		**4**		**4**		**4**		**4**		**4**		**0**		**4**		**0**		**0**
	Pre-trade assistance	1		**2**		**2**		**2**		**2**		**2**		**0**		**2**		**0**		**0**
	Targeted marketing	1		**2**		**2**		**2**		**2**		**2**		**0**		**2**		**0**		**0**
Market Data	Security	3	2	**6**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**
	Real-time DA	3		**6**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
	Personalization	3		**6**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
	Pre-trade assistance	5		**10**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
	Targeted marketing	5		**10**		**0**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
Trade	Security	5	2	**10**	0	**0**	0	**0**	0	**0**	0	**0**	2	**10**	0	**0**	0	**0**	0	**0**
	Real-time DA	5		**10**		**0**		**0**		**0**		**0**		**10**		**0**		**0**		**0**
	Personalization	4		**8**		**0**		**0**		**0**		**0**		**8**		**0**		**0**		**0**
	Pre-trade assistance	4		**8**		**0**		**0**		**0**		**0**		**8**		**0**		**0**		**0**
	Targeted marketing	3		**6**		**0**		**0**		**0**		**0**		**6**		**0**		**0**		**0**
Core banking system	Security	5	0	**0**	2	**10**	2	**10**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**
	Real-time DA	5		**0**		**10**		**10**		**0**		**0**		**0**		**0**		**0**		**0**
	Personalization	2		**0**		**4**		**4**		**0**		**0**		**0**		**0**		**0**		**0**
	Pre-trade assistance	2		**0**		**4**		**4**		**0**		**0**		**0**		**0**		**0**		**0**
	Targeted marketing	1		**0**		**2**		**2**		**0**		**0**		**0**		**0**		**0**		**0**
Personalization	Security	2	0	**0**	2	**4**	0	**0**	2	**4**	2	**4**	0	**0**	2	**4**	2	**4**	0	**0**
	Real-time DA	2		**0**		**4**		**0**		**4**		**4**		**0**		**4**		**4**		**0**
	Personalization	3		**0**		**6**		**0**		**6**		**6**		**0**		**6**		**6**		**0**
	Pre-trade assistance	1		**0**		**2**		**0**		**2**		**2**		**0**		**2**		**2**		**0**
	Targeted marketing	1		**0**		**2**		**0**		**2**		**2**		**0**		**2**		**2**		**0**
Real-time analytics	Security	2	0	**0**	2	**4**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**
	Real-time DA	2		**0**		**4**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
	Personalization	1		**0**		**2**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
	Pre-trade assistance	3		**0**		**6**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
	Targeted marketing	**1**		**0**		**2**		**0**		**0**		**0**		**0**		**0**		**0**		**0**
Capital markets	Security	5	0	**0**	0	**0**	2	**10**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**
	Real-time DA	5		**0**		**0**		**10**		**0**		**0**		**0**		**0**		**0**		**0**
	Personalization	4		**0**		**0**		**8**		**0**		**0**		**0**		**0**		**0**		**0**
	Pre-trade assistance	4		**0**		**0**		**8**		**0**		**0**		**0**		**0**		**0**		**0**
	Targeted marketing	**2**		**0**		**0**		**4**		**0**		**0**		**0**		**0**		**0**		**0**
Insurance	Security	4	0	**0**	0	**0**	2	**8**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**	0	**0**
	Real-time DA	4		**0**		**0**		**8**		**0**		**0**		**0**		**0**		**0**		**0**
	Personalization	3		**0**		**0**		**6**		**0**		**0**		**0**		**0**		**0**		**0**
	Pre-trade assistance	1		**0**		**0**		**2**		**0**		**0**		**0**		**0**		**0**		**0**
	Targeted marketing	1		**0**		**0**		**2**		**0**		**0**		**0**		**0**		**0**		**0**
Authentication/Authorization	Security	5	0	**0**	0	**0**	0	**0**	2	**10**	0	**0**	0	**0**	2	**10**	0	**0**	0	**0**
	Real-time DA	5		**0**		**0**		**0**		**10**		**0**		**0**		**10**		**0**		**0**
	Personalization	2		**0**		**0**		**0**		**4**		**0**		**0**		**4**		**0**		**0**
	Pre-trade assistance	2		**0**		**0**		**0**		**4**		**0**		**0**		**4**		**0**		**0**
	Targeted marketing	1		**0**		**0**		**0**		**2**		**0**		**0**		**2**		**0**		**0**

Risk Management	Security	5	0	**0**	0	**0**	0	**0**	0	**0**	2	**10**	2	**10**	2	**10**	0	**0**	0	**0**
	Real-time DA	4		**0**		**0**		**0**		**0**		**8**		**8**		**8**		**0**		**0**
	Personalization	1		**0**		**0**		**0**		**0**		**2**		**2**		**2**		**0**		**0**
	Pre-trade assistance	2		**0**		**0**		**0**		**0**		**4**		**4**		**4**		**0**		**0**
	Targeted marketing	**1**		**0**		**0**		**0**		**0**		**2**		**2**		**2**		**0**		**0**
Total				**174**		**94**		**156**		**76**		**104**		**68**		**134**		**50**		**32**

4. Conclusion

Financial services should adapt to the digital changes happening in all finance connected processes. The time of legacy systems is up, and the financial institutions need to adapt to the current digital situation and the fast changes that are happening. This study presents the concept of the NoSQL databases with all four types and examples of the most used ones with their main features, and especially how are they used for financial services with examples of companies which have adopted the NoSQL database in their practice. As a result, *the table* was made, which shows an evaluation of NoSQL databases for financial services. Based on it, we can make different decisions either from the rows or columns. If we want to choose a database only for one financial service, we can see if there is an already existing solution based on the different types of NoSQL databases, what is the criteria value and finally the weight of the complex value for this non-relational DB. For example, if we want to select a DB for e-payments, in *the table* we can see that there are solutions based on Document-oriented – Couchbase and MongoDB, Key-value – Amazon Dynamo DB and Redis, and on Column-oriented – MariaDB and Cassandra. After this is seen, a decision can be made about which NoSQL database can be selected for e-payments. On the other side, if we want to choose a non-relational DB for more than one financial service, we can use the columns of the table. For a client to make such a decision, the total result in *the table* 1 below every column is looked at, which shows the sum of all the complex values for this non-relational database. For example, the database with the highest complex result is Couchbase – 174, which means that this DB offers the most solutions for financial services, based on it.

The table created in the previous point is an expert evaluation of the existing solutions based on different types of NoSQL as the criteria used can be changed and new ones can be added, and also new services can be appended, depending on the development of the different types of non-relational databases. For this reason, the spreadsheet below has been created, where criteria have been added and can be changed if there is another expert appraisal, with the different weights and the calculation of the complex values.

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За контакти:
Мариана Ковачева
Редовен докторант към катедра
"Информационни технологии и комуникации"
Университет за национално и световно стопанство
mkovacheva@unwe.bg