SYEROV YURIY
Lviv Polytechnic National University
https://orcid.org/0000-0002-5293-4791
e-mail: yurii.o.sierov@lpnu.ua
TERLETSKA KHRYSTYNA
DraftKings Inc.
https://orcid.org/0009-0002-7302-2625
e-mail: khrystynaterletska1@gmail.com

ANALYZING THE INNOVATIVE ENGINEERING TECHNOLOGY STACK

This research paper delves into the analysis of innovative engineering technology stacks, focusing on five pivotal technologies: C#, SQL, Kafka, AWS, and Snowflake. The study highlights the importance of selecting the right technology stack to ensure efficiency, scalability, and innovation in engineering projects. The paper evaluates each technology through a comprehensive comparative analysis based on attributes such as primary use, key advantages, integration capabilities, scalability, security features, cost, and performance. C# is recognized for its robust application development capabilities, offering high performance and strong integration with the .NET ecosystem. SQL stands out for its efficient data manipulation and compatibility with various database management systems, providing robust security features and high performance. Apache Kafka is noted for its real-time data streaming capabilities, scalability, and fault tolerance, making it a cost-effective solution for handling large data streams. AWS is highlighted for its comprehensive cloud computing services, which offer scalability, flexibility, and extensive integration options supported by robust security services. Snowflake is acclaimed for its advanced data warehousing solutions, providing high performance, scalability, and seamless integration with SQL and AWS. Integrating these technologies into a cohesive engineering technology stack enhances engineering projects' overall performance and scalability. Each technology brings unique strengths, from C#'s application development capabilities to Snowflake's data warehousing solutions. By leveraging the strengths of each component, engineers can create innovative and efficient solutions tailored to specific project requirements. This paper also addresses engineers' challenges in selecting and optimizing technology stacks, emphasizing the need for comprehensive frameworks and methodologies. The insights provided aim to guide engineers, developers, and decision-makers in making informed choices that drive technological excellence and innovation. Ultimately, this study aspires to contribute to both the advancement of scientific knowledge and the development of practical applications, serving as a guide for optimizing technology stacks to meet the evolving demands of diverse industries.
Keywords: Engineering Technology Stack, C#, SQL, Apache Kafka, AWS, Snowflake.

СЄРОВ ЮРІЙ
Національний університет «Львівська політехніка»
ТЕРЛЕЦЬКА ХРИСТИНА
DraftKings Inc.

АНАЛІЗ СТЕКУ ІННОВАЦІЙНИХ ІНЖЕНЕРНИХ ТЕХНОЛОГІЙ

У роботі наведено результати досліджень інноваційних інженерних технологічних стеків: C#, SQL, Kafka, AWS та Snowflake. Проведено порівняльний аналіз цих технологій за основними атрибутами, такими як використання, переваги, інтеграція, масштабованість, безпека, вартість та продуктивність.
Ключові слова: інженерний технологічний стек, C#, SQL, Apache Kafka, AWS, Snowflake

Introduction

The swift advancement of technology has resulted in the creation of increasingly intricate engineering systems. These systems necessitate sophisticated technology stacks that integrate various tools, frameworks, and methodologies to ensure their functionality, scalability, and efficiency. Nevertheless, the dynamic nature of technological progress poses substantial challenges in maintaining and optimizing these stacks. This research paper examines the imperative to analyze and comprehend the components and interactions within contemporary engineering technology stacks.

The issue arises from the lack of comprehensive frameworks and methodologies for evaluating and optimizing technology stacks. Engineers and practitioners frequently encounter challenges in selecting the appropriate tools and technologies corresponding to their specific project requirements and industry standards. This challenge is further exacerbated by the continuous emergence of new technologies, which requires ongoing adaptation and integration.

The correlation between this issue and significant scientific and practical endeavors is apparent. From a scientific perspective, examining engineering technology stacks enhances system design and integration comprehension, providing valuable insights into optimal practices and innovative methodologies. Optimizing technology stacks can increase productivity, reduce costs, and enhance system performance. For instance, incorporating artificial intelligence (AI) [1, 2] and machine learning (ML) [3] into technology stacks can substantially augment predictive maintenance and operational efficiency within manufacturing processes.

Implementing Internet of Things (IoT) [4] devices within technological frameworks facilitates the instantaneous collection and analysis of data, thereby promoting informed decision-making and proactive

problem-solving. These innovations highlight the necessity of establishing comprehensive frameworks for assessing and enhancing technological stacks, ensuring their effectiveness in meeting the evolving demands of diverse industries.

This research paper seeks to address the issue of optimizing engineering technology stacks by presenting a comprehensive analysis of their components and interactions. In doing so, it aspires to contribute to both the advancement of scientific knowledge and the development of practical applications, ultimately serving as a guide for engineers, researchers, and policymakers in their pursuit of technological excellence.

Analysis of related research.

The analysis of innovative engineering technology stacks draws upon a diverse range of research and literature. This section reviews key contributions from various domains, including mechanical, manufacturing, and industrial engineering, programming languages, artificial intelligence, data streaming, cloud computing, and data warehousing. Mott et al. [5] provide a comprehensive overview of the future directions for mechanical, manufacturing, and industrial engineering technology programs. Their work emphasizes the importance of integrating emerging technologies and innovative practices to enhance the educational framework and industry readiness of engineering graduates. This foundational perspective is complemented by Hejlsberg et al. [6], who present the C# language specification. The specification outlines the design and implementation of C#, highlighting its features and capabilities that support robust and scalable software engineering, thus becoming a cornerstone in modern software development.

Building on the theme of software and data engineering, Gadde [7] explores the integration of artificial intelligence into SQL query processing. This study addresses the challenges and opportunities associated with incorporating AI techniques to optimize query performance and enhance data retrieval processes in relational databases. Similarly, Shapira et al. [8] provide an in-depth guide to Apache Kafka, a distributed streaming platform. Their work covers the architecture, deployment, and use cases of Kafka, demonstrating its significance in handling real-time data streams and its role in modern data engineering stacks.

In the realm of cloud computing, Kewate et al. [9] review AWS cloud computing technology, discussing its various services and applications. The review highlights the scalability, flexibility, and cost-effectiveness of AWS, making it a preferred choice for deploying and managing cloud-based solutions. Complementing this, Borra [10] offers a comprehensive review of Snowflake, a modern data warehousing platform. This work examines Snowflake's architecture, features, and performance, showcasing its ability to handle large-scale data analytics and its integration with various data sources.

Educational practices in engineering are also evolving to keep pace with technological advancements. Chow et al. [11] have explored the integration of modern technology stacks in undergraduate software engineering courses. They have demonstrated the effectiveness of teaching testing methodologies using contemporary tools and frameworks, highlighting the importance of adapting educational practices to ensure students are well-prepared for industry demands. In semiconductor technology, Kusuma and Talari [12] conducted a performance analysis of FinFETs using gate stack and workfunction engineering in 14nm technology. Their research provides insights into optimizing FinFET structures, which is crucial for enhancing the performance and efficiency of modern electronic devices. Tsai et al. [13] further investigated the characteristics of HfZrOx gate stack engineering for reliability improvement in 28nm HK/MG CMOS technology. Their findings contribute to understanding gate stack materials and their impact on the reliability and performance of CMOS devices, which are fundamental components in integrated circuits.

Further advancements in FinFET technology were presented by Yeh et al. [14], who developed a low operating power FinFET transistor module featuring scaled gate stack and strain engineering for 32/28nm SoC technology. This work underscores the significance of gate stack scaling and strain engineering in achieving low-power, high-performance transistors for system-on-chip applications.

Collectively, these foundational works contribute to the understanding and development of innovative engineering technology stacks, providing insights into the integration and application of diverse technologies in contemporary engineering practices.

Study objectives formulation

This study aims to conduct a comprehensive comparative analysis of five pivotal technologies – C#, SQL, Kafka, AWS, and Snowflake – to determine their efficiency, scalability, innovation capabilities, usability, and best practices in the engineering field. This analysis will provide valuable insights to help engineers and decision-makers select the most suitable technology stack for their specific needs.

Main part of study

In the contemporary engineering landscape, technology stacks are crucial in determining projects' efficiency, scalability, and innovation potential. A technology stack combines software products and programming languages used to create applications. This study focuses on five pivotal technologies: C#, SQL, Kafka, AWS, and Snowflake, each contributing uniquely to the engineering technology stack.

C# is a versatile programming language developed by Microsoft that is widely used for application development. Its primary benefits include high performance, robustness, and strong integration with the .NET

ecosystem. C# supports vertical and horizontal scalability, making it suitable for various web and desktop applications. Security features such as strong type safety and encryption enhance its reliability. Despite moderate license fees, its performance benchmarks demonstrate its efficiency, such as SHA256: 3.989 µs (Net Core 3.0) [15].

SQL is the standard database management language, recognized for its efficient data manipulation capabilities and compatibility with numerous DBMS. It provides vertical and horizontal scalability and solid security features such as data encryption and access control. Although SQL's cost differs across DBMS, its exceptional performance and extensive community support establish it as a dependable option for data storage and queries. Throughput benchmarks, like 224,358 ops/s (Couchbase Server EE) [16], emphasize its performance strength.

Apache Kafka is a distributed streaming platform for real-time data processing. Its advantages include scalability and fault tolerance, enabling integration with various systems. Kafka supports horizontal scaling and features like encryption and access control. As an open-source technology with enterprise solutions, it is cost-effective and efficient, achieving 605 MB/s throughput and 5 ms (p99) latency.
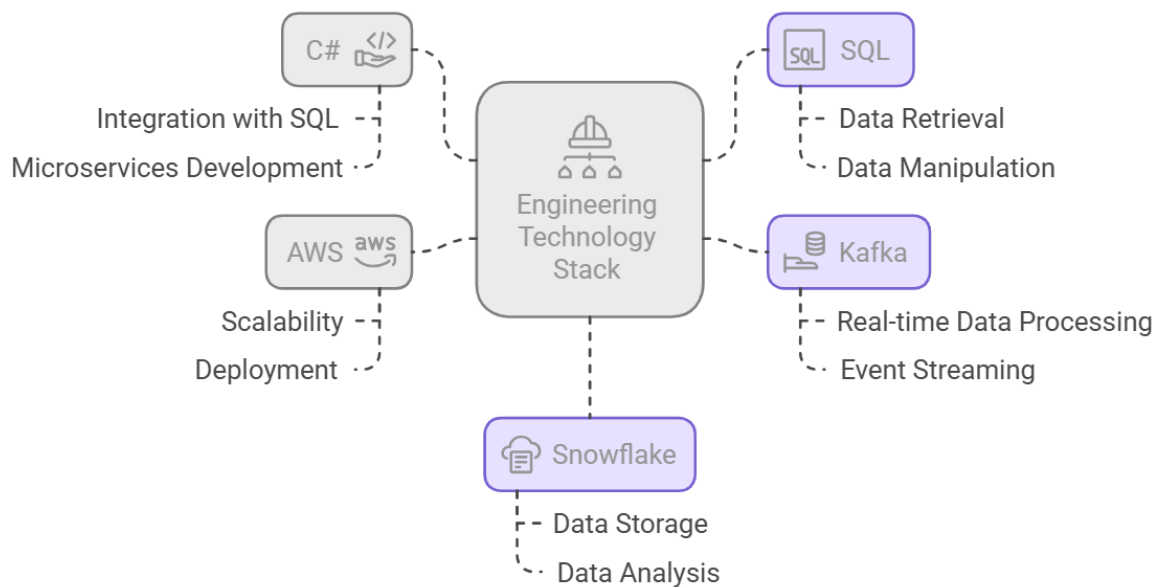

Fig. 1. The scheme of the innovative engineering technology stack

AWS is a comprehensive cloud computing platform offering various services and applications. Its scalability, flexibility, and extensive integration options make it a preferred choice for cloud-based solutions. AWS provides comprehensive security services and operates on a pay-as-you-go model, ensuring cost-effectiveness. Performance benchmarks, such as CPU Speed: 3102 (i7ie.large) [18], demonstrate its capability in hosting, storage, and computing.

Snowflake is a modern data warehousing platform known for its high performance and scalability. It integrates seamlessly with SQL and AWS, offering horizontal scalability and robust security features, including data encryption and compliance. Snowflake operates on a subscription-based model designed for large-scale data analytics and reporting. Performance improvements, such as a 40% query duration improvement [19], showcase its efficiency.

The integration of these technologies into a cohesive engineering technology stack enhances the overall performance and scalability of engineering projects. Each technology brings unique strengths, from C#'s robust application development capabilities to Snowflake's advanced data warehousing solutions. By leveraging the strengths of each component, engineers can create innovative and efficient solutions tailored to specific project requirements.

In the fast-changing engineering field, choosing the right technology stack is crucial for ensuring efficiency, scalability, and innovation. This comparative table comprehensively analyzes five pivotal technologies: C#, SQL, Kafka, AWS, and Snowflake. Each technology is assessed based on various attributes, including primary use, key advantages, integration capabilities, scalability, security features, cost, performance, and additional factors.

Table 1 provides a comprehensive overview that assists engineers, developers, and decision-makers in understanding the strengths and weaknesses of each technology. By facilitating a side-by-side comparison of these technologies, the table promotes informed decision-making and emphasizes the potential of each component to contribute to a robust and innovative engineering technology stack.

Table 1

Feature-by-feature analysis of modern engineering technology stack

Feature	C#	SQL	Kafka	AWS	Snowflake
Primary Use	Application development	Database management	Real-time data streaming	Cloud services	Data warehousing
Key Benefits	High performance, robust	Efficient data manipulation	Scalability, fault tolerance	Scalability, flexibility	High performance, scalability
Integration	.NET ecosystem	Compatible with various DBMS	Integrates with many systems	Extensive integration options	Seamless with SQL, AWS
Scalability	Vertical and horizontal	Vertical and horizontal	Horizontal	Vertical and horizontal	Horizontal
Security Features	Strong type safety, encryption	Data encryption, access control	Encryption, access control	Comprehensive security services	Data encryption, compliance
Cost	License fees	Varies by DBMS	Open-source, enterprise options	Pay-as-you-go	Subscription-based
Performance	High	High	High	High	High
Use Cases	Web apps, desktop apps	Data storage, queries	Event-driven architectures	Hosting, storage, computing	Analytics, reporting
Learning Curve	Moderate	Moderate	Steep	Moderate	Moderate
Community Support	Strong	Strong	Strong	Strong	Growing
Deployment	On-premises, cloud	On-premises, cloud	Cloud, on-premises	Cloud	Cloud
Maintenance	Moderate	Moderate	Low	Low to moderate	Low
Data Handling	Structured, unstructured	Structured	Structured, unstructured	Structured, unstructured	Structured
Latency	Low	Low	Low	Low	Low
Fault Tolerance	High	High	Very high	High	High
Vendor Lock-in	Low	Low	Low	Moderate to high	Moderate
Customization	High	High	High	High	Moderate
Performance Benchmarks	SHA256: 3.989 µs (Net Core 3.0) [15]	Throughput: 224,358 ops/s (Couchbase Server EE) [16]	Throughput: 605 MB/s, Latency: 5 ms (p99) [17]	CPU Speed: 3102 (i7ie.large) [18]	Query Duration: 40% improvement [19]

The comparative analysis presented in this study highlights the importance of selecting the right technology stack for engineering projects. By understanding the strengths and weaknesses of C#, SQL, Kafka, AWS, and Snowflake, engineers, developers, and decision-makers can make informed choices that drive efficiency, scalability, and innovation. The integration of these technologies into a cohesive stack offers significant potential for enhancing contemporary engineering practices.

Conclusions

The rapid advancement of technology has led to increasingly complex engineering systems, requiring sophisticated technology stacks that integrate various tools, frameworks, and methodologies. This paper examined the components and interactions within contemporary engineering technology stacks, focusing on five pivotal technologies: C#, SQL, Kafka, AWS, and Snowflake. Each technology contributes uniquely to the engineering stack. C# offers robust application development capabilities, SQL provides efficient data manipulation, Kafka excels in real-time data streaming, AWS offers scalable cloud services, and Snowflake delivers advanced data warehousing solutions. Integrating these technologies enhances engineering projects' overall performance and scalability. The right technology stack is crucial for efficiency, scalability, and innovation. This study's comparative analysis highlights each technology's strengths and weaknesses, aiding engineers and decision-makers in making informed choices. By harnessing the strengths of each component,

engineers can develop innovative and efficient solutions that cater to specific project needs. This research enhances both scientific understanding and practical use, guiding engineers, researchers, and policymakers in optimizing technology stacks to address the changing demands of various industries.

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