Scaling of Facebook architecture and technology stack with heavy workload: past, present and future

Tole Sutikno[1,2], Laksana Talenta Ahmad[2,3]
[1]Master Program of Electrical Engineering, Faculty of Industrial Technology, Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[2]Embedded Systems and Power Electronics Research Group, Yogyakarta, Indonesia
[3]Department of Information Systems, International Islamic University Malaysia, Kuala Lumpur, Malaysia

Article Info

Article history:

Received Dec 3, 2024
Revised May 8, 2025
Accepted Jun 4, 2025

Keywords:

Architecture
Facebook
Hbase
MyRocks
Technology stack
Workload

ABSTRACT

Leading social media Facebook has improved its architecture to meet user needs. Facebook has improved its systems to handle millions of users with heavy workloads and large datasets using innovative architectural solutions and adaptive strategies. The study examines Facebook's architectural and technological advances in heavy workload and big data. To understand how Facebook scaled with a growing user base and data volume, history and system architecture will be examined. It will also examine how cloud storage and high-performance computing optimize resource utilization and maintain performance during peak user activity. Facebook is managing big data and heavy workloads with new technologies like the hybrid communication model that uses PULL and PUSH strategies for real-time messaging. Facebook switched from HBase to MyRocks for message storage to improve performance as data grew. Architectural scaling and technology stack research must prioritize data storage innovations and optimized communication protocols to handle heavy workloads and big data. The messenger Sync protocol reduces network congestion and improves synchronous communication, reducing resource consumption and maintaining performance under high load. High-performance computing (HPC) and cloud storage should be studied together to support complex compute workflows. This convergence may improve large-scale application infrastructures and encourage interdisciplinary collaboration for scalable and resilient systems.

Corresponding Author:

Tole Sutikno
Master Program of Electrical Engineering, Faculty of Industrial Technology, Universitas Ahmad Dahlan
Yogyakarta, Indonesia
Email: tole@te.uad.ac.id

1. INTRODUCTION

In the fast-changing digital world, being able to expand technology infrastructure is essential for keeping users engaged and ensuring smooth operations. Facebook, a prominent social media platform, provides a noteworthy example of scaling its technology and systems in the face of a significant volume of user-generated content [1]–[12]. In the past, Facebook's engineering teams have faced many issues with heavy workloads and the need to handle large amounts of data. By using new architectural solutions and flexible strategies, the platform has consistently improved its systems, enabling a strong response to the needs of millions of users at once. This study looks into the details of Facebook's growth, exploring past methods, current practices, and future directions related to big data management and scalability. By examining these aspects, we hope to reveal the key principles that have supported Facebook's ability to adapt and its effects on the larger tech environment.

In a world centered on social connections, Facebook's rapid growth since its inception in 2004 illustrates its innovative use of technology and the ways users engage with the platform. The user base expanded from a small Harvard network to over 2.8 billion monthly active users globally, reflecting a significant demand for social media that transcends geographical and demographic boundaries. This remarkable growth necessitated structural changes within Facebook to effectively manage the vast amounts of data generated by user interactions and content sharing. As noted in [13], the platform has evolved through the implementation of advanced technologies, including real-time messaging, user updates, and efficient data retrieval systems. Furthermore, the development of scalable solutions like the Messenger Sync protocol, which greatly reduces non-media data consumption, underscores Facebook's commitment to improving user experience as demands increase. This continuous evolution emphasizes the crucial relationship between architecture and user needs in Facebook's strategic direction.

The ability to scale technology architecture effectively is important for maintaining performance and reliability in applications with high traffic, especially in data-heavy environments. Facebook has continuously changed its architectural parts to keep up with the rapid increase in user interactions and data sharing, focusing on the resilience of its messaging systems. Proper scaling ensures optimal resource utilization, preventing potential bottlenecks during high workloads. For example, standard scheduling methods like first in, first out (FIFO) often do not meet demands, as mentioned in [14]. By using smart scheduling methods that consider job sizes and node loads, organizations can improve efficiency and response times, achieving a balance between resource distribution for short and long jobs. In the end, as systems grow, creating flexible scaling strategies becomes essential, highlighting a proactive approach in technology architecture that prepares for future needs while maximizing existing capabilities.

The management of big data in today's data environments involves handling large volumes, rapid processing, and diverse formats, which closely relate to the concept of heavy workloads. Heavy workloads occur when systems are required to process substantial amounts of transactional data and conduct real-time analyses, as exemplified by platforms like Facebook that manage billions of messages daily [15]. This complexity demands robust infrastructures capable of scaling efficiently to meet evolving demands, which is important for preserving stable operational performance. Big data refers to datasets that exceed the capacity of traditional data-processing tools, thereby necessitating advanced algorithms and systems for effective management. For instance, the integration of high-performance computing and cloud storage signifies a major advancement, enhancing computing power while reducing costs. This evolution makes it essential for new technologies to address the challenges associated with heavy workloads in big data processing [16]. Consequently, grasping these concepts is vital for tackling the challenges and seizing opportunities within the technology sector, which relies heavily on data.

The research study aims to examine the changes, current methods, and future directions of Facebook's architectural and technological improvements concerning heavy workloads and big data requirements. By analyzing past data management and system design, this study will demonstrate how Facebook's scaling methods have effectively addressed the challenges associated with an expanding user base and large volumes of data. This research will look at how using cloud storage and powerful computing helps improve efficiency, making sure resources are used well and performance stays steady during busy times. Furthermore, it will explore the impact of various scaling techniques, such as transitioning from HBase to MyRocks [17], [18], to enhance data retrieval. The research will also highlight Shivang's findings [16] regarding the importance of system architecture in high-demand scenarios. Collectively, these objectives will point out the importance of architectural changes in supporting growth within social media platforms. A thorough analysis of the evolution of Facebook's technology and structure is essential, especially given the challenges related to managing large data sets and heavy usage. The structure of the study begins with an introduction that outlines the background and significance of the topic. This is followed by a brief literature review that synthesizes previous work on scalable architectures and innovative strategies employed by Facebook to manage real-time user engagement and data processing [15]. The study will then review Facebook's technological history, comparing earlier systems with current ones, particularly focusing on the integration of cloud storage in high-performance computing setups to boost performance and reduce costs [16]. Finally, the conclusion will not only summarize the findings but also provide recommendations for future research and practices, illustrating how technological advancements influence the ongoing growth of social media platforms like Facebook.

2. HISTORICAL CONTEXT OF FACEBOOK'S ARCHITECTURE

The architectural development of Facebook illustrates complex responses to the increasing demands of a rapidly expanding user base, reflecting the broader context of technological changes in the digital age. Initially, Facebook's architecture was simple, utilizing a Linux, Apache, MySQL, and PHP (LAMP) stack as its primary platform. Figure 1 demonstrates that the Facebook messaging component initially depended on

HBase, a distributed file system (HDFS) based on Hadoop. HBase is an open-source, non-relational distributed database inspired by Google BigTable and programmed in Java. The engineering team selected it for its high write throughput and low latency. Key features of this distributed system included horizontal scalability, high consistency, and reliability. Other services, such as the internal monitoring system, search indexing, streaming data analysis, and data scraping, also employed HBase in production. However, as user activity surged, the evolving needs necessitated a redesign of the platform's technical framework. This historical transition involved incorporating Erlang for real-time messaging, resulting in a sophisticated chat system that processes billions of messages daily. Additionally, tackling the essential issue of user presence information was critical in developing scalable systems, as real-time tracking of user statuses required substantial resources [15]. As Facebook expanded, the transition from HBase to MyRocks exemplified its adaptability to big data challenges, where enhancing performance became vital for maintaining operational stability under heavy workloads [17]–[19]. Thus, Facebook's architectural evolution highlights technological adaptation and signifies a major shift in managing complex digital interactions.

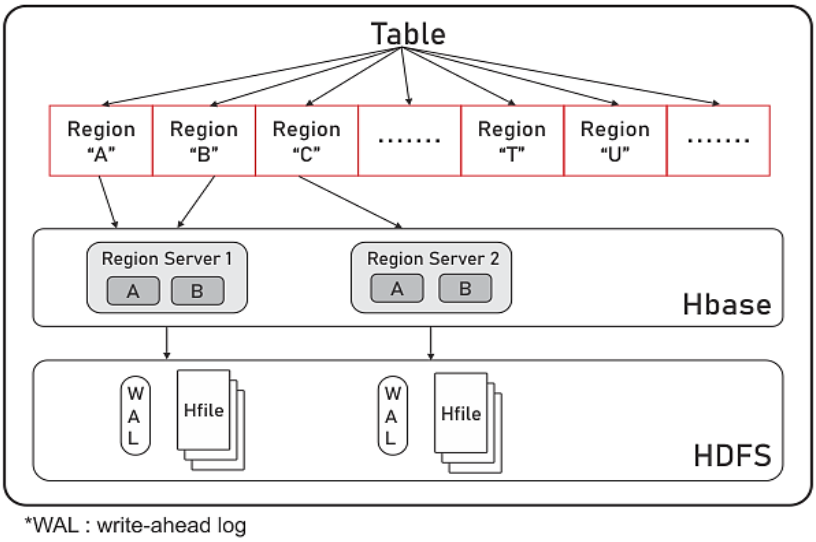

Figure 1. HBase deployment at Facebook

2.1. Initial architecture and technology stack at launch

Facebook designed its initial setup to facilitate rapid growth and efficient management of user data from the outset. At its inception, Facebook utilized a technology stack that included PHP for its web interface and a MySQL database for effective data storage and retrieval. This foundational setup enabled quick launching and continuous enhancements, which were crucial during the platform's swift expansion. As the number of users grew, performance issues emerged, necessitating modifications to the stack. The implementation of Erlang channel servers for message management provided a robust solution for real-time communications, addressing essential needs as user demands escalated [15]. Furthermore, the transition from HBase to MyRocks indicated a strategic pivot aimed at enhancing data processing efficiency while navigating the complexities associated with big data tasks. By integrating these technologies, Facebook established a resilient architecture capable of accommodating the substantial demands of its users, setting a precedent for future advancements in its technology stack.

2.2. Evolution of Facebook's infrastructure over the years

The development of Facebook's infrastructure demonstrates its capacity to adapt to increasing user demands and technological changes. Initially, the site operated on a basic LAMP setup to accommodate rapid user growth. However, as data and user engagement expanded, Facebook transitioned to a more sophisticated, modular system. The upgrade included the implementation of the Messenger Sync protocol, which reduced non-media data usage by 40% and alleviated network traffic. Furthermore, the shift from HBase to MyRocks for message storage reflects Facebook's commitment to effectively managing large datasets. Enhanced messaging capabilities, featuring components like Erlang channel servers and C++ user presence modules, bolster the infrastructure's ability to support the platform's intricate yet robust system. This ongoing evolution underscores Facebook's strategic investment in refining its architecture to maintain strong performance under heavy usage, illustrating a dedication to scaling and reliability in a data-intensive environment [15], [20].

2.3. Key challenges faced in early scaling efforts

The shift to a scalable structure presented significant challenges during Facebook's growth, particularly as the demand for real-time communication and content sharing surged. A key issue was the effective management of user presence information, which became increasingly complicated under high traffic conditions. According to Shivang [15], the chat services system needed to process billions of daily messages while ensuring optimal performance during peak times. Facebook had to implement improved load balancing techniques and transition from HBase to MyRocks for message storage—decisions that underscored the operational difficulties associated with scaling. Additionally, the integration of PULL and PUSH communication methods required a careful balance between performance and the management of system resources. These challenges demonstrate that early scaling necessitated not only new technologies but also strategic planning to address infrastructure limitations and enhance user experience [13], [21].

2.4. Major technological innovations introduced

The changes in Facebook's structure have been marked by major tech improvements that solved problems linked to scaling and large data amounts. One key development is the use of a mixed communication model in its chat system, which uses both PULL and PUSH methods. This feature helps manage user presence and messaging during heavy loads, as mentioned in [15]. This strategy shows a wider trend toward using specific edge devices and plans to reduce network delays, which is especially important for real-time apps in rural areas [22]. Also, the addition of MyRocks, which improves how databases store data, marks an important move toward better data retrieval, boosting both performance and scalability. By putting these new technologies into action, Facebook changed its tech framework, providing a strong base for managing more complicated workloads while setting the stage for future developments in big data systems.

2.5. Lessons learned from past scaling experiences

The complex growth process experienced by leading tech companies imparts crucial lessons that influence both current and future systems, particularly in managing large tasks and big data. A key takeaway from Facebook's growth initiatives is the necessity of enhancing communication methods to improve performance during peak traffic periods. For instance, the Messenger Sync protocol reduced non-media data usage by 40%, alleviating network strain and illustrating the importance of protocol efficiency in message handling. Additionally, as high-performance computing (HPC) combines with cloud technologies, it's important to connect different storage systems to prevent interruptions in scientific work [16]. By prioritizing the expansion of load balancers, Facebook successfully minimized chat service downtimes, demonstrating that proactive infrastructure changes are essential for maintaining service reliability as user numbers surge [15]. Consequently, drawing lessons from past experiences enables organizations to develop robust and adaptable systems that can meet growing data demands.

3. CURRENT ARCHITECTURE AND TECHNOLOGY STACK

Getting how today's architecture and technology stack used by big tech companies works is important for judging their capacity to handle more workloads and large data as shown in Figure 2. Facebook's architecture shows this, changing from a simple one-piece design to a complicated system based on microservices that is meant for growth and effectiveness when many users are active. Important parts, like the mixed communication model used in its live chat feature, show how Facebook mixes PULL and PUSH techniques to improve how resources are used and response times in messaging services. This structure uses a mix of JavaScript, PHP, and Erlang, along with modern tools like MyRocks for handling databases, which helps manage user interactions within the huge number of messages sent daily [15]. This level of complexity has helped the platform to cut down on service failures and keep users connected during busy times, proving how new technology stacks can improve system performance [23].

3.1. Overview of Facebook's current architecture

The design of Facebook has changed a lot to meet the growing needs for users interacting and managing data. At the heart of this system is a mixed communication model that uses both PULL and PUSH methods, enabling users to interact in real-time while reducing delays. This system effectively backs the messaging feature, which handles billions of messages each day, showing the need for efficiency in such large volume management. Plus, using different programming languages like JavaScript for the user interface, PHP for the web layer, and Erlang for managing messages helps improve performance across various services. Additionally, moving from Hbase to MyRocks for storing messages shows Facebook's dedication to using the latest database technologies to improve speed of retrieval and data reliability. The ongoing changes to their architecture, as noted in [15], emphasize the strategic need to combine cloud and HPC resources, as stated by [16], ultimately creating a strong and expandable system that can manage its large user base and complicated tasks.

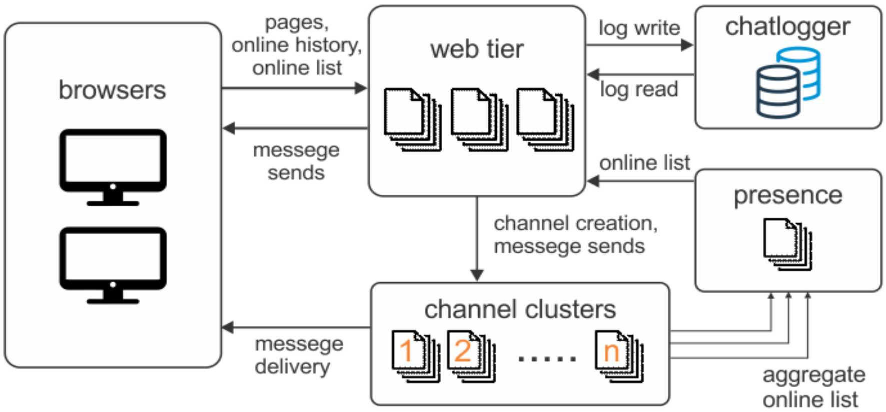

Figure 2. Facebook's real-time chat architecture and technology stack

3.2. Technologies used for data storage and management

The complex area of data storage and management technologies has changed a lot to keep up with the increasing amount and complexity of data produced on platforms like Facebook. Key to this system is integrating different database systems that are built to effectively manage various workloads. Facebook started using Hbase for message storage but later moved to MyRocks, improving how data is retrieved by using the special features of Flash memory and MySQL's structured storage model, thus enhancing performance [15]. Moreover, combining HPC with cloud storage technologies offers a good path for scalability, enabling flexible resource allocation while improving cost efficiency. As explained in the convergence assessment model, using cloud setups allows for strong data sharing between HPC and cloud environments, creating a smooth workflow that improves both performance and resource use [16]. This blend of technologies shows a forward-looking method to tackle the big data issues faced by high-traffic applications like Facebook.

3.3. Load balancing and traffic management strategies

Managing network traffic in large architectures is complicated and needs strong load balancing and traffic management methods that can change with demand. When Facebook faced rising user activity, especially on its messaging platform, the engineering team used various techniques to keep performance smooth. In the realm of software-defined networking (SDN), good load balancing is crucial to reduce delays between controllers and switches, especially during busy times [24]. This is supported by clever methods like migration strategies that improve resource use by watching and adjusting to traffic patterns, which helps maintain service quality during peak times [25]. Using these methods not only made the architecture more scalable but also enhanced response times and reliability. In the end, the ongoing development of these techniques shows their important role in maintaining application performance in an age marked by big data and high user engagement, as seen in Facebook's shift from Hbase to MyRocks for faster message retrieval, improving both speed and scalability [15].

3.4. Real-time data processing capabilities

The ability to handle data right away is key for today's apps, especially for social media platforms like Facebook. With billions of messages sent daily, Facebook's system is carefully built to manage this load effectively. Using a mix of PULL and PUSH communication methods, the platform balances heavy tasks like tracking user presence, which is important for real-time interaction. The use of advanced processing systems, such as the Hadoop ecosystem combined with Apache Spark, allows for quick data analysis and sentiment detection on a large scale, tackling the issues that come with a lot of user-generated content [13]. Additionally, the creation and improvement of tools like the messenger Sync protocol show a big improvement in real-time functions, cutting down on data transfer while boosting user satisfaction [13]. These developments not only show Facebook’s quick response to what users want but also emphasize the vital role of real-time data handling in keeping up with changing tech environments [26].

3.5. Security and privacy considerations in scaling

As Facebook grows its architecture to handle large workloads and huge datasets, many security and privacy issues come up that need careful attention. The mix of technologies, especially in the full-stack JavaScript framework, brings unique vulnerabilities that could put user data at risk, making it essential for developers to tackle possible threats from both the client side and server side [27]. Additionally, using cloud storage along with on-premise HPC solutions creates a situation where poor management of data-sharing interfaces can result in unauthorized access or data leaks [16]. The architecture used in Facebook’s real-time chat system shows these difficulties; keeping track of user presence information requires secure transmission protocols to stop interception or tampering during high activity, underscoring the need for broad security measures that cover both application and infrastructure layers. Therefore, as Facebook continues to develop its technology stack, focusing on security is crucial to maintaining user trust and meeting data protection laws.

4. CHALLENGES OF SCALING WITH HEAVY WORKLOAD AND BIG DATA

Scaling technologies in environments with heavy workloads and big data brings many challenges that need careful strategies. Key difficulties include efficiently sharing resources and improving data storage solutions, which are essential to keep performance high under pressure. To deal with the space issues. The engineering team at Facebook wrote a new MySQL database engine, MyRocks [18], which reduced space usage by 50% and also helped improve the write efficiency as shown in Figure 3. Over time, Facebook migrated its user-facing database engine from InnoDB to MyRocks. The migration was relatively straightforward, as only the DB engines underwent changes, while the core MySQL technology remained unchanged. The move from Hadoop systems to MyRocks in Facebook’s setup shows a strategic change focused on handling large amounts of data while bettering query performance. This shift highlights a wider need to tackle delays while maintaining strong data integrity, creating a challenge in terms of both speed and reliability. Additionally, Facebook’s development of the messenger Sync protocol underscores the significance of innovative communication techniques in mitigating network congestion in big data environments. As companies deal with the complexities of real-time data processing, these experiences highlight the crucial connection between architectural changes and the operational needs of scalable, data-heavy applications.

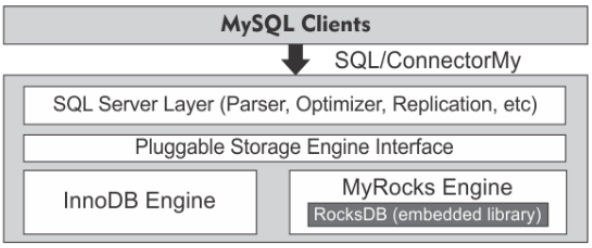

Figure 3. MyRocks MySQL storage engine written by Facebook [18]

4.1. Performance bottlenecks in data processing

Finding and fixing performance issues in data processing is a big problem, especially as platforms such as Facebook keep expanding their systems to handle large workloads and massive amounts of data. These issues often come from poor resource allocation, slow data retrieval methods, and high network latency, which can disrupt real-time processing and user engagement. According to [28], using large models in big data processing shows how performance improvement strategies can solve these problems by increasing computing efficiency and better resource allocation. Additionally, the fast digital changes affecting small and medium businesses highlight the need for scalable solutions that can handle increased data loads without hurting system performance-this is closely related to the performance issues seen in larger systems like Facebook. Using strong data management systems, as mentioned in [29], can also help ease these problems, ensuring that system performance and user experience are preserved even with rising operational challenges. Therefore, a broad strategy that considers both system design and resource management is crucial for overcoming ongoing performance issues that hinder efficient data processing in busy environments.

4.2. Issues related to data consistency and integrity

Keeping data consistent and intact is a big challenge, especially in systems that deal with lots of users and large datasets. For platforms like Facebook, which handle billions of messages every day using complex systems, it's critical to keep a consistent state between distributed databases. Problems can come up when multiple transactions happen at the same time, which can cause data issues. This shows the need for strong system designs that can handle heavy loads without losing data integrity. The mixed communication method Facebook uses, involving both PULL and PUSH tactics, shows a smart way to reduce these risks while keeping real-time functions. Also, moving from Hbase to MyRocks for storing messages shows a focus on improving performance and data trustworthiness, as noted in [15]. Good solutions should aim for regular checks and fixes on data to keep user information precise and reliable, despite the challenges of big data settings, a worry discussed in studies on user data leaks in current literature [30].

4.3. Scalability challenges in distributed systems

In distributed systems, scalability is a complicated problem affecting both design and how well they operate. As services grow, there are new challenges with handling more user requests and large amounts of data. For example, Facebook deals with these issues in its real-time chat system, which needs to process billions of messages every day while keeping track of user statuses. The mix of PULL and PUSH communication methods shows the struggle to keep the system quick while also managing its resources [15]. Additionally, the difference between old and cloud storage designs makes scalability even harder, particularly as hybrid systems become more common. Research on this mix shows that using cloud storage can save money and improve efficiency, but it also adds performance challenges that must be carefully managed to prevent slowdowns [16]. Thus, achieving effective scalability in distributed systems depends on new architectural strategies that combine different technologies while addressing their existing challenges.

4.4. Resource allocation and cost management

Good resource use and cost control are very important for growing complex systems like Facebook's, especially with heavy workloads and large data sets. Using serverless architectures has been helpful, allowing for flexible resource use that cuts costs by about 30% while also helping with scalability [15]. This fits with Facebook's approach, where they always try to improve their technology tools to boost performance and control costs. For example, using a combination of PULL and PUSH communication methods shows how Facebook balances resource expenditure while keeping service reliably available, showing a clear understanding of the cost factors in real-time systems [31]. Furthermore, by using advanced data management tools like MyRocks to improve message retrieval, Facebook demonstrates a focus on both enhancing performance and reducing infrastructure costs-both key for handling the challenges of big data [32].

4.5. Impact of user behavior on system performance

User actions greatly affect how well a system works, especially for big applications like Facebook, where user interactions produce a lot of real-time data. Differences in user activity, like how often they send messages and how involved they are, create changing workloads that put a strain on the system's ability to scale well. For instance, the setup of the real-time chat system needs to handle billions of messages each day while maintaining low delays and high uptime. Thus, the hybrid communication model that mixes PULL and PUSH techniques, explained in [15], highlights the complicated relationship between user behavior and system requirements. Likewise, analyzing user-generated content to understand public opinion, as discussed in [13], shows how changes in user activity can influence the efficiency of backend processes, impacting overall system performance. Therefore, it's crucial to regularly monitor and adjust system parts to prevent performance drops due to unpredictable user actions, emphasizing the importance of efficient designs that can handle high workload situations.

5. FUTURE DIRECTIONS AND INNOVATIONS

Facebook is facing problems with heavy workloads and lots of data, so using new technologies is very important for its future plans. The way its messaging and chat services can grow shows that improvements are needed; for example, the messenger Sync protocol has cut down on non-media data use by 40%, which shows there is room for better performance in communication tools. Additionally, the use of SDN with internet of things (IoT) applications, mentioned in recent studies, could help improve how data is managed across different platforms [33]. By using advanced methods like text mining and natural language processing, noted in discussions about E-commerce [34], Facebook can better understand how users interact and what they like, leading to new ideas in user engagement. The link between these technological improvements allows Facebook to not only expand its services but also change the way users experience the digital world.

5.1. Emerging technologies that could influence scaling

The ongoing growth of new technologies has important effects on developing large architectures, especially in social media. Recent progress in cloud computing, machine learning, and distributed databases opens ways to improve performance and better manage data. For example, moving to a federated architecture deals with the complex balance of cost and complexity amid rising data needs, which is essential for companies like Facebook that handle huge streams of user interactions [35]. Furthermore, adding real-time analytics tech allows systems to quickly process data and generate insights, which is vital for keeping users engaged and running efficiently. This shift reflects the architectural strategies seen in Facebook's messaging setup, where tools like MyRocks have changed data storage methods, speeding up data retrieval while reducing pressure on systems [15]. As these trends develop, their overall effect on scalability will be more noticeable, requiring a forward-thinking approach to design and tech integration.

5.2. Predictions for Facebook's architecture evolution

As Facebook works through a complicated data environment, it must advance its structure to meet growing needs for both scale and performance. Going towards a more connected and spread-out system, as new studies suggest, may help Facebook manage its different data sources and combine older systems better [35]. Also, the move to edge computing offers a chance for Facebook to reduce delays and enhance user experience, especially in less served areas [22]. Utilizing low-energy hardware boosters and new management methods, Facebook can simplify how it deploys applications and makes better use of resources, improving overall system dependability. The engineering challenges of its existing real-time chat system illustrate this; a new, flexible design could allow for easier scaling while keeping costs under control. In conclusion, these forecasts for Facebook's structure highlight the importance of a flexible, responsive system that can handle large workloads and effectively use big data, as shown by information from the company's ongoing progress in messaging and presence management technology [15].

5.3. Potential for artificial intelligence and machine learning integration

In the last few years, adding artificial intelligence and machine learning to large systems, like those used by Facebook, has changed how data is processed and analyzed. By using complex algorithms, Facebook's systems can improve user experiences through personalized interactions and manage the huge amounts of data created each day, especially in real-time apps like its chat service. The use of artificial intelligence and machine learning also helps in better resource management and forecast analytics, making it easier to handle user presence information, which is a vital and demanding task [15]. Additionally, progress in these technologies can improve message queuing and network traffic management, as shown by the messenger Sync protocols' better data usage [36]. Therefore, integrating artificial intelligence and machine learning into large systems not only solves current problems but also helps organizations quickly adjust to future needs.

5.4. Strategies for sustainable scaling practices

The quest for sustainable scaling methods needs smart strategies that can change with new workloads and tech progress. Good scalability requires strong architecture and a good grasp of the tools found in the big data world. For example, as shown in new studies, combining different open-source tools into a unified system helps handle and analyze data well, especially in high-user situations like Facebook's setup [26]. Moreover, using machine learning methods, like naive Bayes and support vector machines for studying sentiment, shows how user-generated content processing can be improved, as these techniques make it quicker to respond to real-time data [13]. Sustainable scaling methods should also focus on reducing resource use while boosting performance, by using cloud systems to ease on-site hardware limits. In summary, the combination of careful tool choice, clever algorithm use, and cloud integration makes for a well-rounded way to keep scalability in busy environments.

5.5. Anticipated regulatory impacts on technology stack

Future rules are likely to greatly impact the technology used by companies like Facebook, particularly as they deal with big data and heavy workloads. Previous studies show that the merging of cloud and HPC technologies creates an important balance between compliance and efficiency, requiring new ideas in the base architecture [16]. Regulators might set strict data privacy rules that will affect storage solutions and data management practices, pushing organizations to use stronger, clearer systems for handling user data.

Additionally, the expected growth of data spaces, as discussed in new research, will need a change in architecture to allow easy data sharing while following regulatory rules [37]. These modifications will need not only changes in technical abilities but also a complete rethinking of system design to ensure quick compliance while boosting operational performance in changing legal environments.

6. CONCLUSION

Facebook's system, which manages large workloads and significant data volumes, has encountered various challenges and solutions that may inform future technological advancements. The shift from HBase to MyRocks signifies a major transformation in data management focused on optimizing operations in a rapidly evolving environment. Facebook's architectural update has unveiled challenges and innovative ideas that have facilitated its growth. The implementation of a hybrid communication method that employs both PULL and PUSH mechanisms for rapid messaging effectively engages users. The migration from HBase to MyRocks for message storage underscores Facebook's dedication to performance as data volumes increase, illustrating the importance of a robust technological framework to handle big data. These technical advancements set a standard for future modifications in data-intensive environments, reflecting an ongoing trend of change and adaptability. Future research in architectural scaling and technology should prioritize innovative data storage solutions and enhanced communication protocols to meet the rising demands of heavy workloads and big data. Companies like Facebook must keep pace with the swift increase in user interactions and content creation, as illustrated by their transition from HBase to MyRocks for message storage and the implementation of the Messenger Sync protocol to alleviate network congestion and improve synchronous communication. Collaborative research and development among industry leaders can stimulate innovation, leading to robust, efficient architectures capable of navigating uncertainties. The pursuit of continuous innovation presents both challenges and opportunities, motivating technologists to devise solutions that uphold system performance and enhance the user experience.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to Universitas Ahmad Dahlan (UAD), the Embedded System and Power Electronics Research Group (ESPERG), and the International Islamic University Malaysia (IIUM) for their invaluable support and contributions to this research. The facilities, guidance, and collaborative environment provided by these institutions were essential to the successful completion and publication of this work.

FUNDING INFORMATION

The research was funded by PT. Intelektual Pustaka Media Utama (IPMU) under contract number 08/RST-E/IPMU/I/2024, which supported the facilitation of this work.

AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Tole Sutikno	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓		✓
Laksana Talenta Ahmad		✓				✓		✓		✓				

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board or equivalent committee.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

REFERENCES

[1] D. D. Albesta, M. L. Jonathan, M. Jawad, O. Hardiawan, and D. Suhartono, "The impact of sentiment analysis from user on Facebook to enhanced the service quality," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 11, no. 4, pp. 3424–3433, 2021, doi: 10.11591/ijece.v11i4.pp3424-3433.

[2] S. Ramondt, M. Zijlstra, P. Kerkhof, and E.-M. Merz, "Barriers to blood donation on social media: an analysis of Facebook and Twitter posts," *Transfusion*, vol. 60, no. 10, pp. 2294–2306, 2020, doi: 10.1111/trf.15998.

[3] L. Eger, D. Egerová, L. Tomczyk, and M. Krystoň, "How universities communicate with public using Facebook page," *International Journal of Media and Information Literacy*, vol. 6, no. 1, pp. 88–99, 2021, doi: 10.13187/IJMIL.2021.1.88.

[4] F. A. Carrillat, A. d'Astous, and E. M. Grégoire, "Leveraging social media to enhance recruitment effectiveness: A Facebook experiment," *Internet Research*, vol. 24, no. 4, pp. 474–495, 2014, doi: 10.1108/IntR-07-2013-0142.

[5] P. Lázaro-Rodríguez, "Digital news on public libraries: Media mapping and thematic and consumption analysis based on Facebook interactions," *Profesional de la Informacion*, vol. 30, no. 1, pp. 1–13, 2021, doi: 10.3145/epi.2021.ene.15.

[6] M. Kowal, "The value of a like: Facebook, viral posts, and campaign finance in US congressional elections," *Media and Communication*, vol. 11, no. 3, pp. 153–163, 2023, doi: 10.17645/mac.v11i3.6661.

[7] E. Skogerbø and A. H. Krumsvik, "Newspapers, Facebook and Twitter: Intermedial agenda setting in local election campaigns," *Journalism Practice*, vol. 9, no. 3, pp. 350–366, 2015, doi: 10.1080/17512786.2014.950471.

[8] I. Kelpšienė and C. Dallas, "Battle or ballet? Metaphors archaeological Facebook administrators live by," *Journal of Community Archaeology and Heritage*, vol. 10, no. 2, pp. 107–127, 2023, doi: 10.1080/20518196.2022.2157566.

[9] F. Said, D. Zainal, and A. A. Jalil, "Big data analytics capabilities (BDAC) and sustainability reporting on Facebook: does tone at the top matter?," *Cogent Business and Management*, vol. 10, no. 1, 2023, doi: 10.1080/23311975.2023.2186745.

[10] J. A. Smith *et al.*, "Using social media in health literacy research: a promising example involving Facebook with young Aboriginal and Torres Strait Islander males from the Top End of the Northern Territory," *Health Promotion Journal of Australia*, vol. 32, no. S1, pp. 186–191, 2021, doi: 10.1002/hpja.421.

[11] A. Ahmad, L. Alhanshali, I. S. Jefferson, and R. Dellavalle, "Cochrane skin group's global social media reach: content analysis of Facebook, Instagram, and Twitter Posts," *JMIR Dermatology*, vol. 5, no. 4, 2022, doi: 10.2196/40905.

[12] M. Ballings, D. Van den Poel, and M. Bogaert, "Social media optimization: identifying an optimal strategy for increasing network size on Facebook," *Omega (United Kingdom)*, vol. 59, pp. 15–25, Mar. 2016, doi: 10.1016/j.omega.2015.04.017.

[13] W. G. Mutasher and A. F. Aljuboori, "Real time big data sentiment analysis and classification of Facebook," *Webology*, vol. 19, no. 1, pp. 1112–1127, Jan. 2022, doi: 10.14704/web/v19i1/web19076.

[14] M. V. Dhamecha, "Improved mapreduce algorithm with efficiency in structure and relations in the large body of the data (bigdata)," Gujarat Technological University, 2020.

[15] Shivang, "Facebook real-time chat architecture scaling with over multi-billion messages daily," *scaleyourapp*, 2023. https://shorturl.at/ieEnm.

[16] F. Gadban, "Analyzing convergence opportunities of HPC and cloud for data intensive science," Universität Hamburg, 2022.

[17] A. Eisenman *et al.*, "Reducing DRAM footprint with NVM in Facebook," in *Proceedings of the 13th EuroSys Conference, EuroSys 2018*, 2018, vol. 2018-January, doi: 10.1145/3190508.3190524.

[18] Y. Matsunobu, S. Dong, and H. Lee, "MyRocks: LSM-tree database storage engine serving Facebook's social graph," *Proceedings of the VLDB Endowment*, vol. 13, no. 12, pp. 3217–3230, 2020, doi: 10.14778/3415478.3415546.

[19] J. S. Hurwitz, A. Nugent, F. Halper, and M. Kaufman, *Big Data For Dummies*. Wiley, 2013.

[20] J. Kreps, *I Heart Logs: Event Data, Stream Processing, and Data Integration*. O'Reilly Media, 2014.

[21] T. Ciesielski, "Development and optimization of big data pipelines in fintech: a comprehensive analysis of technology integration and workflow efficiency," Universidad Politécnica de Madrid, 2024.

[22] S. Bäurle, "A flexible, application-focused benchmarking suite for edge infrastructures," Technische Universität München, 2021.

[23] N. Lee, *Facebook Nation*. New York, NY: Springer New York, 2021.

[24] P. S. Tiwana and J. Singh, "Load optimization accessions, ramification the QoS in software defined networking," in *2023 International Conference on Artificial Intelligence and Smart Communication (AISC)*, Jan. 2023, pp. 1013–1017, doi: 10.1109/AISC56616.2023.10085328.

[25] A. K. Jain, P. Kumari, R. Dhull, K. Jindal, and S. Raza, "Enhancing software-defined networking with dynamic load balancing and fault tolerance using a q-learning approach," *Concurrency and Computation: Practice and Experience*, Oct. 2024, doi: 10.1002/cpe.8298.

[26] A. Nemec, "Navigating big data processing software stacks," Masaryk University, 2021.

[27] C.-A. Staicu, "Enhancing the security and privacy of full-stack javascript web applications," *software-lab*, 2020. www.software-lab.org.

[28] Z. Wen, P. Wang, J. Zhang, and P. Xiong, "Study on the performance optimization and application of big model in big data processing," in *2024 6th International Conference on Data-driven Optimization of Complex Systems (DOCS)*, Aug. 2024, pp. 650–657, doi: 10.1109/DOCS63458.2024.10704388.

[29] E. Johnson, O. B. S.-Lande, G. S. Adeleke, C. P. Amajuoyi, and B. D. Simpson, "Developing scalable data solutions for small and medium enterprises: Challenges and best practices," *International Journal of Management and Entrepreneurship Research*, vol. 6, no. 6, pp. 1910–1935, Jun. 2024, doi: 10.51594/ijmer.v6i6.1206.

[30] D. Straňák, "Infrastructure and support tools for processing and analyzing large structured data," Masaryk University, 2023.

[31] F. A. Ezeugwa, "Evaluating the integration of edge computing and serverless architectures for enhancing scalability and sustainability in cloud-based big data management," *Journal of Engineering Research and Reports*, vol. 26, no. 7, pp. 347–365, Jul. 2024, doi: 10.9734/jerr/2024/v26i71214.

[32] A. Islam, "Hybrid cloud databases for big data analytics: a review of architecture, performance, and cost efficiency," *International journal of management information systems and data science*, vol. 1, no. 4, pp. 96–114, Sep. 2024, doi: 10.62304/ijmisds.v1i04.208.

[33] I. E. Kamarudin, M. A. Ameedeen, M. F. A. Razak, and A. Zabidi, "Software defined internet of things in smart city: a review," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 32, no. 2, p. 915, Nov. 2023, doi: 10.11591/ijeecs.v32.i2.pp915-924.

[34] K. Mahajan, D. Bordoloi, C. Barboza, D. Bansal, B. Madhava Rao, and S. Varshini S, "Big data with cloud computing model for customer need identification in e-commerce industry," in *2024 5th International Conference on Recent Trends in Computer Science and Technology (ICRTCST)*, Apr. 2024, pp. 155–159, doi: 10.1109/ICRTCST61793.2024.10578354.

[35] P. Ahlawat *et al.*, "A new architecture to manage data costs and complexity," *Boston Consulting Group (BCG)*, pp. 1–12, 2023.

[36] A. B. T.-P.Hong, L. Serrano-Estrada, A. Saxena, "Deep learning for social media data analytics," *Advanced Deep Learning Applications in Big Data Analytics*, vol. 113, pp. 68–91, 2022, [Online]. Available: http://services.igi-global.com/resolvedoi/resolve.aspx?doi=10.4018/978-1-7998-2791-7.ch004%0Ahttps://link.springer.com/10.1007/978-3-031-10869-3.

[37] E. Curry, S. Scerri, and T. Tuikka, Eds., *Data Spaces*. Cham: Springer International Publishing, 2022.

BIOGRAPHIES OF AUTHORS

Tole Sutikno is a lecturer and the head of the Master Program of Electrical Engineering at the Faculty of Industrial Technology, Universitas Ahmad Dahlan (UAD) in Yogyakarta, Indonesia. He received his Bachelor of Engineering from Universitas Diponegoro in 1999, Master of Engineering from Universitas Gadjah Mada in 2004, and Doctor of Philosophy in Electrical Engineering from Universiti Teknologi Malaysia in 2016. All three degrees are in the Electrical Engineering area. He has been a Professor at UAD in Yogyakarta, Indonesia, since July 2023, following his tenure as an associate professor in June 2008. He is the Editor-in-Chief of TELKOMNIKA and Head of the Embedded Systems and Power Electronics Research Group (ESPERG). He is listed as one of the top 2% of researchers worldwide, according to Stanford University and Elsevier BV's list of the most influential scientists from 2021 to the present. His research interests cover digital design, industrial applications, industrial electronics, industrial informatics, power electronics, motor drives, renewable energy, FPGA applications, embedded systems, artificial intelligence, intelligent control, digital libraries, and information technology. He can be contacted at email: tole@te.uad.ac.id, or tole@ee.uad.ac.id.

Laksana Talenta Ahmad is a researcher at the Embedded Systems and Power Electronics Research Group (ESPERG) in Yogyakarta, Indonesia, and a student in the Bachelor of Information Technology (BIT) program, Department of Information Systems (DIS), Kulliyyah of Information and Communication Technology (KICT) at the International Islamic University Malaysia (IIUM) in Kuala Lumpur, Malaysia. His research interests encompass various aspects of information technology, including organizational informatics, database programming, robotics, and artificial intelligence. He can be contacted at email: laksanatadz@gmail.com.