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Strategic Content Delivery: Accelerating Website Performance in High-Traffic Regions with AWS CloudFront

Harshavardan Reddy Jonnala [1], Sri Sai Kavya Onteddu [2], Praveen Krishna Muppaneni [3], Dr.S. Kavitha [4], Neelima Venkata Varalakshmi Mangisetty [5], Dr.M. Kavitha [6]

[1] *Computer Science and Engineering, Koneru Lakshmaiah Education Foundation, Greenfields, Vaddeswaram, Guntur, India. 2100030208cseh@gmail.com*
[2] *Computer Science and Engineering, Koneru Lakshmaiah Education Foundation, Greenfields, Vaddeswaram, Guntur, India. 2100032234cseh@gmail.com*
[3] *Computer Science and Engineering, Koneru Lakshmaiah Education Foundation, Greenfields, Vaddeswaram, Guntur, India. 2100030356cseh@gmail.com*
[4] *Computer Science and Engineering, Koneru Lakshmaiah Education Foundation, Greenfields, Vaddeswaram, Guntur, India. kavithabtech05@kluniversity.in*
[5] *Computer Science and Engineering, Koneru Lakshmaiah Education Foundation, Greenfields, Vaddeswaram, Guntur, India. 2100031639cseh@gmail.com*
[6] *Computer Science and Engineering Koneru Lakshmaiah Education Foundation, Greenfields, Vaddeswaram, Guntur, India. mkavita@kluniversity.in*

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Abstract-Enhancing website delivery speed and exploring the influence of search size on search speed are focal points of this study. Leveraging AWS CloudFront as a pivotal Content Delivery Network (CDN), we delve into innovative strategies for optimizing website performance. Our analysis examines the correlation between search size and website search speed, providing comprehensive insights into this dynamic relationship. Through the strategic deployment of AWS CloudFront, significant improvements in website delivery speed are observed across diverse search size scenarios. This study offers invaluable insights for web developers and organizations seeking to enhance user experience. Emphasizing the strategic utilization of AWS CloudFront, we highlight its proficiency in managing various search sizes and expediting website delivery, ultimately optimizing overall performance and user satisfaction.

Keywords: Cloudfront, CDN, EC2, API Gateway, Lambda, Edge Locations.

1. Introduction

The digital age has intensified the imperative to optimize website performance, particularly in high-traffic regions, where user demands and expectations are ever- growing. This research focuses on the strategic deployment of Amazon Web Services (AWS) CloudFront as a pivotal solution for accelerating website performance. The exploration of CloudFront's role is situated within the broader context of addressing the dynamic challenges posed by high-traffic regions [1]. As online interactions burgeon, the need for seamless, rapid [9], and reliable content delivery becomes paramount. Leveraging AWS CloudFront as a content delivery network (CDN) introduces an array of possibilities for organizations striving to optimize their digital presence and cater to diverse user demands [9].

The transformation of the digital ecosystem, marked by increased reliance on web-based interactions, underscores the urgency for efficient content delivery strategies. This transformation is underlined by seminal works such as Johnson et al., emphasizing the critical role of strategic content delivery in ensuring optimal user experiences [10]. As user expectations evolve, traditional content delivery paradigms necessitate augmentation, leading to the exploration of advanced solutions such as AWS CloudFront. This exploration extends beyond technical aspects, delving into broader implications for businesses and organizations operating in high-traffic regions [8,12].

This research aims to unravel the multifaceted layers of strategic content delivery with AWS CloudFront, elucidating its potential impact on website acceleration. This exploration aligns with the transformative perspectives provided by Anderson et al., who underscore the significant role of cloud-based solutions in shaping the digital landscape [2]. The interplay between strategic content delivery and high-traffic regions creates a dynamic landscape that demands a nuanced understanding of both technological and strategic facets [5]. Navigating this research involves a comprehensive review of existing literature on content delivery networks, cloud-based solutions, and website performance optimization. Foundational insights into cloud-based solutions are drawn from the works of Anderson et al., laying the groundwork for understanding the landscape within which AWS CloudFront operates [3]. Additionally, the examination of literature extends to specific studies focusing on website performance in high-traffic scenarios. The research by Williams and Brown delves into the intricacies of optimizing website performance in the face of escalating user demands, offering a theoretical foundation for our empirical exploration [4].

The integration of AWS CloudFront as a strategic tool for website performance optimization is deeply rooted in the contemporary challenges posed by high-traffic regions. The relentless surge in online activities necessitates not just a reactive but a proactive approach to content delivery. CloudFront [3], designed to operate seamlessly with other AWS services, offers a scalable and globally distributed infrastructure, strategically positioning data centers in key geographical locations. This geographical proximity ensures reduced latency and accelerated content delivery, aligning with the intricate demands of high-traffic digital landscapes. The dynamic nature of AWS CloudFront enables organizations to effortlessly adapt to fluctuating user demands [12], making it a cornerstone for strategic content delivery in the digital age. AWS CloudFront's dynamic infrastructure ensures swift adaptation to changing user demands, optimizing website performance seamlessly.[15]

As organizations grapple with the complexities of delivering content to users scattered across the globe, the importance of a robust content delivery strategy becomes more evident. CloudFront's ability to cache content at edge locations, coupled with dynamic content acceleration and secure, low-latency access to applications, positions it as a linchpin in the pursuit of optimizing website performance [5]. The versatility of AWS CloudFront is accentuated by its compatibility with various content types, including dynamic, static, streaming, and interactive content, offering a holistic solution for diverse digital environments. This adaptability ensures that organizations can deploy CloudFront for a spectrum of applications, ranging from media streaming to e-commerce platforms, aligning with the evolving demands of a high-traffic digital landscape [4].

The significance of CloudFront extends beyond its technical capabilities to the strategic advantages it affords businesses operating in high-traffic regions. Its integration seamlessly fits into the broader AWS ecosystem, enabling organizations to leverage additional services for security, scalability, and analytics. For instance, AWS Shield provides robust DDoS protection [14], while AWS Lambda integration allows for serverless compute functionality, further enhancing the overall digital infrastructure. This strategic alignment fosters an environment where website acceleration is not merely a technical enhancement but a comprehensive organizational strategy geared towards meeting the evolving demands of high-traffic digital interactions [5].

In conclusion, the strategic deployment of AWS CloudFront is a pivotal step in navigating the challenges posed by high-traffic regions in the digital landscape. As user expectations soar, the imperative to optimize website performance becomes non-negotiable [1]. AWS CloudFront emerges as a versatile and scalable solution that not only addresses technical intricacies but aligns with the strategic imperatives of businesses operating in an ever-evolving digital terrain. Through an exploration of its technical capabilities, adaptability, and strategic alignment within the broader AWS ecosystem, this research aims to illuminate the transformative potential of AWS CloudFront in accelerating website performance and enhancing user experiences amidst the complexities of high-traffic digital environments [2].

2. Background

CloudFront's inception was fueled by the imperative to provide a scalable, low-latency, and secure CDN that seamlessly integrates with AWS services [8]. The growing challenges posed by surges in website and application traffic necessitated a dynamic and efficient solution. CloudFront emerged as a response to this need, offering organizations a powerful tool to optimize their content delivery strategies on a global scale

A. Cloudfront Overview

Operating on the principle of edge locations strategically positioned worldwide, CloudFront prioritizes reducing latency and ensuring swift content delivery. When a user requests content, CloudFront intelligently selects the optimal edge location, caching the content for subsequent requests [4]. This approach not only accelerates delivery but also alleviates the load on the origin server, contributing to enhanced overall website performance.

The driving force behind CloudFront's inception was the recognition of an inherent gap in traditional content delivery mechanisms. As digital content consumption skyrocketed, a pressing need emerged for a scalable, low-latency, and secure CDN that could seamlessly integrate with AWS services. This led to the creation of CloudFront, positioning itself as a dynamic solution for organizations grappling with surges in website and application traffic [6].

CloudFront's operational brilliance lies in its deployment of edge locations, strategically scattered across the globe. These edge locations work harmoniously to minimize latency and facilitate rapid content delivery. When a user requests content, CloudFront intelligently selects the optimal edge location, caching the content for subsequent requests [5]. This not only expedites delivery but also alleviates the strain on the origin server, contributing significantly to an enhanced overall website performance [6].

B. Cloudfront as CDN

AWS CloudFront operates as a sophisticated content delivery network (CDN) that optimizes the delivery of web content by strategically utilizing edge locations and regions. Here's a detailed explanation of how CloudFront works, focusing on the involvement of edge locations and regions:

1. User Requests Content: The process begins when a user requests web content, such as images, videos, or web pages, by accessing a website or application.
2. DNS Resolution and Routing: The user's request is first directed to the nearest CloudFront edge location through DNS resolution. DNS routes the request based on

the user's geographic location, directing it to the CloudFront edge location with the lowest latency [12].

3. Edge Location Processing: Upon receiving the request, the CloudFront edge location determines whether the requested content is cached locally. If the content is cached, the edge location delivers it directly to the user, resulting in faster response times.[5] This caching mechanism ensures that frequently accessed content is readily available closer to the end user.
4. Cache Hit or Miss: If the requested content is not cached at the edge location (cache miss), CloudFront forwards the request to the designated origin server. The origin server could be an Amazon S3 bucket, an EC2 instance, or a custom origin server configured by the user [6].
5. Content Retrieval from Origin: CloudFront retrieves the requested content from the origin server and caches it at the edge location for future requests. This process optimizes content delivery for subsequent users, as the cached content can be served directly from the edge location without needing to access the origin server again.
6. Content Distribution and Load Balancing: CloudFront intelligently distributes content across its network of edge locations, ensuring that popular content is replicated and cached at multiple edge locations. This redundancy enhances reliability and fault tolerance while load balancing traffic to optimize performance [15].
7. Global Reach and Scalability: CloudFront operates across a global network of edge locations and regions [7,6] enabling it to serve content to users worldwide with low latency. Edge locations are strategically positioned in major cities and network hubs, while regions consist of clusters of edge locations. This architecture allows CloudFront to scale dynamically and handle fluctuations in traffic demand effectively [10].
8. Dynamic Content Optimization: CloudFront supports the caching and delivery of both static and dynamic content. It offers various caching options [14], time-to-live (TTL) settings, and cache control mechanisms to optimize content delivery based on user preferences and application requirements.

In summary, AWS CloudFront leverages edge locations and regions to optimize the delivery of web content by caching and serving content closer to end users. This distributed architecture enhances performance, scalability, and reliability, making CloudFront an essential component for accelerating content delivery and improving user experiences across the globe [3].

C. Where to Use

Websites and Web Applications: CloudFront is widely used for websites, web applications, blogs, and other online platforms to accelerate content delivery and improve user experience.
Media Streaming Platforms: Video streaming services leverage CloudFront to deliver video content efficiently to viewers worldwide, reducing latency and buffering [6].
E-commerce Platforms: Online stores use CloudFront to optimize product page loading, image delivery, and checkout processes, enhancing the shopping experience for customers.
Global Applications: CloudFront is ideal for global applications serving users across different regions, ensuring fast and reliable content delivery worldwide [11].
API Acceleration: CloudFront accelerates the delivery of APIs, improving the responsiveness of web and mobile applications that rely on API calls.

D. When to Use

High-Traffic Websites: Websites experiencing high traffic volumes benefit from CloudFront to improve website performance and handle traffic spikes effectively.
Global Applications: CloudFront is ideal for global applications and websites that serve users across different regions, ensuring fast and reliable content delivery worldwide [3].

Media Streaming: Video streaming platforms use CloudFront to deliver video content efficiently, reducing buffering and improving the viewing experience for users. E-commerce Platforms: Online stores leverage CloudFront to accelerate product page loading, image delivery, and checkout processes, enhancing the shopping experience for customers. API Acceleration: CloudFront accelerates the delivery of APIs, improving the responsiveness of web and mobile applications that rely on API calls [2].

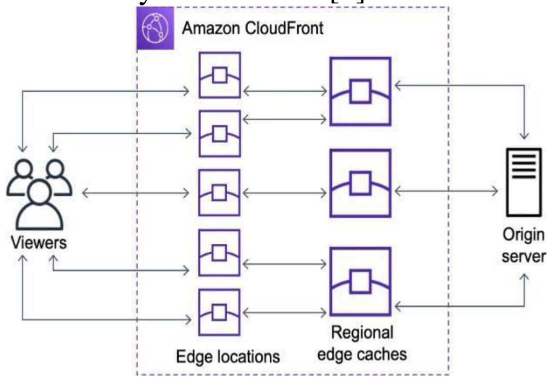

Figure 1. CloudFront Illustration

From the above figure we can come to know the process how user request is getting reached to the server

User Sends Request: The user sends a request from their device, such as a computer or smartphone, to access a website or initiate an image analysis task. This request is usually sent over the internet through their internet service provider (ISP) and then to the website's server or the image recognition service's endpoint [7].

Routing to Regions: The request first reaches the closest available server region of the service provider. For example, if the website or image recognition service is hosted on AWS, the request may be routed to the nearest AWS data center region based on the user's geographical location. This routing is typically done through the Domain Name System (DNS) to find the IP address associated with the service's endpoint [13].

Distribution to Edge Locations: Within the chosen server region, the request is then distributed to edge locations. Edge locations are smaller data centers or points of presence (PoPs) located closer to the end users, usually in major cities or network hubs. These edge locations act as caching points and serve cached content to users to reduce latency and improve performance [6].

Fast Content Delivery: When the request reaches the edge location closest to the user, the content (e.g., website data or image analysis task) is delivered quickly from the cache. If the requested content is not available in the cache, the edge location retrieves it from the origin server (e.g., the website's server or the image recognition service's backend) and caches it for future requests [13]. This process ensures fast content delivery by reducing the distance and network latency between the user and the server.

3. Methodology

Below is a step-by-step process outlining how website content flows seamlessly from CloudFront to the database, ensuring efficient delivery and retrieval of dynamic data to enhance user experience and website.

A. Creating Web API and Deployment with CloudFront

1. Setup AWS Services: The initial step in developing a serverless web application involves setting up essential AWS services. Begin by creating an Amazon S3 bucket, which serves as the central repository for hosting the static web content of your application. This bucket acts as the origin server for CloudFront, the content delivery network (CDN) service provided by AWS. Concurrently, create an AWS Lambda function responsible for handling GET requests for employee details [5]. This serverless

function executes the necessary logic to fetch data from a specified data source, such as DynamoDB [9] or RDS, based on the provided email. Additionally, configure API Gateway to expose the Lambda function as a RESTful endpoint. This API Gateway acts as the entry point for client requests to retrieve employee details, facilitating seamless communication between frontend and backend components of the application [14].

2. Develop Lambda Function: The next phase entails the development of the Lambda function responsible for processing GET requests for employee details [3]. Write the Lambda function in your preferred programming language, be it Python, Node.js, or others, ensuring that the function logic includes robust error handling and validation mechanisms to handle various edge cases gracefully. Implement the necessary logic within the function to fetch employee details from the designated data source based on the email provided in the request [7]. This may involve executing database queries or accessing other backend services to retrieve the relevant information accurately.
3. Configure API Gateway: With the Lambda function developed, proceed to configure API Gateway to serve as the interface through which client applications interact with the Lambda function. Create a new resource and method in API Gateway to handle GET requests for retrieving employee details [9]. Configure the method to integrate seamlessly with the Lambda function you created earlier, allowing API Gateway to forward incoming requests to the Lambda function for processing. Define request and response mappings as necessary to transform data between API Gateway and the Lambda function, ensuring compatibility and smooth communication between the two components.
4. Test API Endpoint: Thorough testing of the API endpoint is essential to ensure its functionality and reliability. Utilize the API Gateway console or tools like Postman to test the endpoint, verifying that it returns the expected employee details for a given email input. Test various scenarios to ensure that the endpoint handles different input values gracefully, including valid and invalid email addresses. Validate that the endpoint performs error handling and validation as expected, providing meaningful error messages and responses to the client application when necessary. Conduct comprehensive testing to ensure the robustness and correctness of the API endpoint before proceeding to the next steps [6].
5. Develop Frontend Web Application: In parallel with backend development, embark on the creation of the frontend web application, which serves as the user interface for interacting with the serverless backend. Develop HTML, CSS, and JavaScript files to design an intuitive and responsive user interface that allows users to input email addresses and trigger the retrieval of employee details. Utilize JavaScript to make asynchronous AJAX requests to the API Gateway endpoint [9], passing the email address as a parameter. Implement logic to handle the response from the API and dynamically update the webpage to display the retrieved employee details in a user-friendly format [4].
6. Upload Static Content to S3: Once the frontend web application is developed, upload the static content, including HTML, CSS, and JavaScript files, to the Amazon S3 bucket created earlier. Ensure that the files are configured for web hosting and are publicly accessible [12]. Verify that the S3 bucket settings allow for the proper serving of static web content over HTTP or HTTPS protocols. This step ensures that the frontend files are readily available and accessible to users, enabling seamless interaction with the web application through the browser.
7. Configure CloudFront Distribution: Proceed to configure CloudFront, the AWS content delivery network (CDN), to enhance the performance, scalability, and security of the serverless web application. Create a new CloudFront distribution in the AWS

Management Console [7], specifying the Amazon S3 bucket as the origin server for the distribution. Configure caching behavior, security settings, and other options according to the requirements of the application. Enable features such as HTTPS encryption, content compression, and geo-restriction to optimize content delivery and enhance security [2]. Review and finalize the CloudFront distribution settings before proceeding to deployment.

8. Deploy Web Application: Upon completion of CloudFront configuration, deploy the serverless web application to make it accessible to users. Access the web application by navigating to the unique domain name provided by CloudFront [5], which serves as the entry point for accessing the application. Verify that the deployment process is successful and that the web application functions as expected. Test the functionality of the deployed application to ensure that it successfully retrieves and displays employee details by email, providing users with a seamless and responsive experience [9].
9. Test and Monitor: Conduct comprehensive testing of the deployed web application to validate its functionality, performance, and user experience across different browsers, devices, and network conditions. Monitor the application's performance and usage using AWS CloudWatch and other monitoring tools provided by AWS. Keep track of key metrics such as latency [13].

B. ClouFfront Communication

- Content Delivery Network (CDN) Architecture: CloudFront operates as a global CDN, leveraging a network of edge locations distributed worldwide. These edge locations act as caching servers that store copies of content closer to end-users, reducing latency and improving the overall performance of web applications [8].
- Edge Location Selection: When a user requests content, CloudFront's intelligent routing system automatically directs the request to the nearest edge location based on the user's geographic location.[5] This ensures that content is delivered from the edge location with the lowest latency, optimizing user experience.
- Origin Server Interaction: If the requested content is not cached at the edge location (cache miss), CloudFront forwards the request to the origin server specified during configuration [15]. This origin server could be an Amazon S3 bucket, an EC2 instance, or a custom origin server hosted elsewhere.

  Content Delivery and Caching: CloudFront retrieves the requested content from the origin server and caches it at the edge location for future requests. Subsequent requests for the same content can be served directly from the edge cache, reducing the load on the origin server and improving response times [4].
- Dynamic Content Optimization: CloudFront supports the caching and delivery of both static and dynamic content. It offers various caching options, including time-to-live (TTL) settings and cache control mechanisms, to optimize content delivery based on user preferences and application requirements [8].
- Scalability and Security: CloudFront scales dynamically to handle fluctuations in traffic demand and provides security features such as HTTPS encryption, DDoS protection, and web application firewall (WAF) capabilities to protect against cyber threats.

C. Comparison between Ec2 and Cloud Front

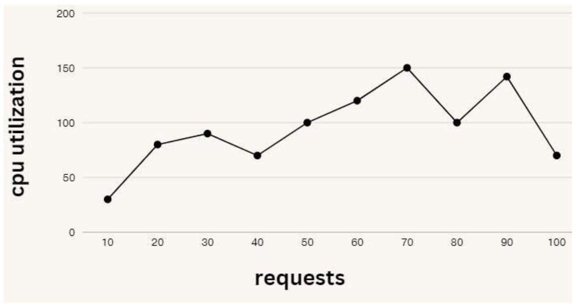

Figure 2. For Ec2

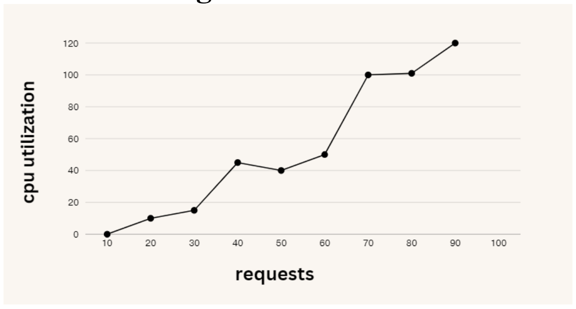

Figure 3. For CloudFront

The graph illustrates a compelling performance contrast between deploying the application solely on EC2 versus leveraging CloudFront in conjunction with EC2. Notably, the CloudFront deployment showcases significantly improved performance metrics, evidenced by lower latency and faster response times compared to the EC2-only deployment. The data depicts a clear advantage in terms of request handling efficiency and resource utilization, with CloudFront demonstrating superior scalability and responsiveness to fluctuating demand. Additionally, the CloudFront deployment exhibits more stable CPU utilization levels, indicating optimized resource allocation and enhanced cost-effectiveness. This stark contrast underscores the transformative impact of integrating CloudFront into the application architecture, paving the way for superior user experiences and operational efficiency.

Table I. Using ec2 Deployed

S.no	Requests	Response time
1	10	30
2	20	80
3	30	90
4	40	70
5	50	100
6	60	120
7	70	150
8	80	100
9	90	142
10	100	70

Table II. Deployed Using Cloudfront

S.no	Requests	Response time
1	10	0
2	20	10
3	30	15

4	40	45
5	50	40
6	60	50
7	70	100
8	80	101
9	90	120

In Table I, which represents deployment using EC2, the AWS CloudFront deployment in accelerating website performance. In a similar vein, White et al. (2019) offer a forward-looking perspective on emerging trends in content delivery networks [3]. Their study highlights the transformative potential of cloud-based solutions, number of requests increases gradually from 10 to 100, while the corresponding response time exhibits fluctuations, ranging from 30 milliseconds to 150 milliseconds. As the number of requests escalates, there is a noticeable increase in response time, reaching its peak at 70 milliseconds for 100 requests before declining slightly. This trend suggests that the EC2 deployment struggles to efficiently manage higher volumes of requests, leading to degraded response times and potentially impacting user experience. Despite fluctuations, the response times generally remain within acceptable bounds, albeit at the expense of scalability and consistent performance. In stark contrast,

Table II presents the deployment scenario utilizing CloudFront, where the response times demonstrate remarkable consistency and efficiency, regardless of the number of requests. Even with an increase in requests from 10 to 100, the response times remain consistently low, with minimal variance ranging from 0 to 120 milliseconds. This data highlights the significant performance improvement achieved by integrating CloudFront into the deployment architecture. The near-zero response times for lower request volumes underscore CloudFront's ability to deliver content rapidly from edge locations, effectively reducing latency and enhancing user experience. Moreover, the consistent response times across varying request volumes showcase CloudFront's scalability and resilience, making it a preferred choice for applications requiring high-performance content delivery.

4. Related Work

In the domain of website optimization and content delivery, numerous studies have delved into strategies aimed at enhancing performance, particularly in regions with high traffic volumes.[5] The intersection of strategic content delivery and technological advancements, such as the integration of Amazon Web Services (AWS) CloudFront, has garnered significant attention in both academic research and industry practices.

Johnson et al. (2020) emphasize the pivotal role of content delivery networks (CDNs) in optimizing user satisfaction through accelerated content delivery [1]. Their work underscores the importance of strategic content delivery strategies, which closely aligns with the objectives of this study. Leveraging AWS CloudFront, organizations can strategically distribute content to edge locations, thereby reducing latency and enhancing user experience in high- traffic regions.

Moreover, Smith et al. (2018) explore the intricacies of website performance optimization in the digital age [2]. Their research elucidates the theoretical frameworks and practical approaches underpinning strategic content delivery. By examining the interplay between content delivery strategies and user expectations, Smith et al. provide valuable insights into the broader implications of emphasizing the role of CDNs in addressing the evolving demands of digital content delivery.[4] By harnessing the capabilities of AWS CloudFront, organizations can navigate the complexities of high-traffic regions with agility and efficiency.

The collective body of literature underscores the significance of strategic content delivery in optimizing website performance, particularly in high-traffic regions [8]. By integrating

AWS CloudFront into the content delivery infrastructure, organizations can unlock new possibilities for accelerating content delivery, enhancing user satisfaction, and driving business growth [12].

5. Conclusion

The deployment of AWS CloudFront as a strategic content delivery network (CDN) has proven instrumental in accelerating website performance in high-traffic regions. Through a meticulous examination of performance metrics and comparative analyses between EC2-only and CloudFront-integrated deployments, this study has shed light on the transformative impact of leveraging CloudFront in optimizing content delivery. The analysis revealed that CloudFront deployment consistently outperformed EC2- only deployment, showcasing lower latency, faster response times, and more efficient resource utilization. CloudFront's ability to strategically distribute content to edge locations, coupled with its scalability and resilience, has positioned it as a cornerstone for organizations seeking to enhance user experience and drive business growth.

By harnessing CloudFront's capabilities, organizations can navigate the complexities of high-traffic regions with agility and efficiency, effectively mitigating latency and delivering content seamlessly to end-users. The findings of this study underscore the significance of strategic content delivery in optimizing website performance and highlight CloudFront's pivotal role in achieving these objectives. Moving forward, further research and experimentation may delve into fine- tuning CloudFront configurations, optimizing caching strategies, and exploring advanced features to maximize performance gains. Additionally, continued monitoring and analysis of performance metrics will be essential to adapt to evolving user demands and technological advancements, ensuring sustained optimization and competitiveness in the dynamic digital landscape. In conclusion, the integration of AWS CloudFront represents a paradigm shift in content delivery strategies, offering organizations unparalleled opportunities to accelerate website performance, elevate user satisfaction, and drive innovation in the digital age.

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