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Evaluating Network Performance in a Web-Based Augmented Reality System for Lipmatte Color Recommendation

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ABSTRACT

This study presents the Augmented Reality (AR) Lipmatte Recommendation System aimed at enhancing user experience and optimizing performance within the beauty industry. By utilizing AR technology, the system offers real-time virtual lipstick try-ons and personalized shade suggestions based on users' skin tones. Key functionalities include user registration and secure authentication, ensuring personalized and protected access. The system's performance focuses on delivering precise AR overlays for virtual try-ons, emphasizing low latency and seamless interaction across varied network environments. Network performance was analyzed in two scenarios: client-to-server data transfer and resource loading. Performance metrics indicated that the system efficiently managed increased network traffic and resource demands, demonstrating scalability and responsiveness. For instance, the average network transfer rate increased from 1.29 KB/s with four devices to 2.47 KB/s with twenty devices, confirming the system's ability to handle larger data flows efficiently. Similarly, resource loading times varied, with an average loading time of 3.76 ms for four devices, improving to 2.44 ms with eight devices, and peaking at 3.96 ms with sixteen devices before stabilizing at 2.80 ms with twenty devices. These findings underscore the necessity of a robust network infrastructure to ensure a seamless AR experience, which is vital for enhancing consumer engagement, brand loyalty, and purchasing decisions in beauty applications. This research highlights the significant potential of AR technology in modernizing the beauty shopping experience while illustrating the critical role of network performance in achieving optimal user satisfaction. Future investigations should explore advanced dynamic resource allocation algorithms and emerging technologies, such as 5G connectivity and edge computing, to further enhance real-time AR applications and better understand user interactions with AR in retail settings.

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1. INTRODUCTION

Recent advancements in Augmented Reality (AR) technology have enabled users to view virtual objects in real time within the physical world. AR is part of the broader concept of mixed reality, which integrates both physical and virtual environments (Ghazwani & Smith, 2020). AR systems can operate in either single-user or collaborative settings, depending on the number of participants involved. Typically, AR systems feature two types of users: passive users, who observe virtual content without interacting, and active users, who engage with the virtual content through user interfaces. The type of interaction is determined by the interface. For instance, AR browsers may only allow passive viewing of virtual objects, while tangible user interfaces facilitate interaction through physical objects (Ghazwani & Smith, 2020).

AR has been widely adopted across various sectors, from retail to healthcare, due to its ability to blend the virtual and physical worlds. In the cosmetics industry, AR's potential is particularly valuable, offering users a virtual try-on experience that reduces the need for physical product testers. Diloy, Núñez, Quirao, Panis, and Vasquez (2023) explored AR applications for beauty industry professionals and consumers, aiming to minimize the reliance on physical testers and enable contactless interaction through AR. This approach seeks to modernize outdated practices in cosmetic sales, addressing inefficiencies in the system. The study also examined the social impact of using interactive technology to enhance customer engagement, support, and enjoyment during the shopping experience. However, such enjoyment can be dampened by technical issues, such as network latency. Therefore, this paper focuses on an online AR application, specifically evaluating network performance in a web-based AR system for personalized lip matte color recommendations.

2. LITERATURE

The rapid advancement of AR technology has significantly impacted various industries, particularly in beauty and fashion, where it is prominently utilized through Virtual Try-On (VTO) applications in e-commerce. AR allows users to virtually experience products like makeup, transforming the online shopping process. A critical factor in the success of these systems is network performance, which directly affects the smoothness and responsiveness of AR experiences. This review synthesizes key findings from studies on AR applications in beauty and fashion to highlight the importance of network performance in web-based AR systems, including virtual lipstick color recommendation tools. Several studies emphasize the role of AR in enhancing user experience and consumer behavior. Morabet (2021) highlights how AR-based VTO improves both practical and hedonic values for users, boosting confidence and purchase intentions when it comes to beauty products. Nalic (2024) further elaborates on AR's contribution to improving user interaction, satisfaction, and brand loyalty, particularly in the fashion and cosmetics industries. Both studies underscore the importance of delivering a seamless AR experience, with network performance playing a crucial role in achieving this.

Technological advancements in AR have also led to more sophisticated applications. For example, MakeApp (Diloy et al., 2023) relies on real-time facial feature mapping and machine learning, with network factors such as latency and accuracy being critical to maintaining user trust and engagement. Hwangbo et al. (2020) argue that a robust network infrastructure is vital for real-time 3D rendering, which directly influences customer satisfaction and return rates. Ghazwani and Smith (2020) also stress the importance of network performance in designing user-friendly AR interfaces, emphasizing that low latency and precise tracking are essential to maintaining immersion. Network performance remains critical across various AR applications. Hung, Yang, and Hsieh (2021) underscore its significance in complex AR makeup systems, noting that delays or disruptions significantly impair the user experience. As AR technology continues to evolve and become more sophisticated, the demand for a strong and reliable network infrastructure becomes increasingly vital. The role of network infrastructure in supporting online application operations is

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fundamental to ensuring a smooth and efficient user experience. A robust network ensures that applications can scale reliably to meet user demands, particularly in cloud-based services. For example, video streaming platforms require high bandwidth to enable users to stream high-definition content without interruptions (Maguire et al., 2020). In the context of cloud computing platforms like Amazon Web Services (AWS) and Microsoft Azure, a flexible and strong network infrastructure is essential for offering elastic scalability, allowing applications to grow while maintaining reliability (Al-Shabibi, 2019). In particular, AR applications require real-time 3D image processing and high data flow, demands that can only be met by advanced network infrastructures with low latency and high processing capabilities (Ghazwani & Smith, 2020).

In conclusion, the literature consistently identifies network performance as a key determinant of user experience in AR-based beauty applications. Low latency, high bandwidth, and reliability are crucial for optimizing user engagement and influencing purchase behavior in web-based AR systems, such as virtual lipstick recommendation tools.

3. METHODOLOGY

This methodology outlines the design, implementation, and performance evaluation of a three-tier Web-Based Augmented Reality (AR) System for Lipmatte Color Recommendation. The system enables users to capture a lip image using their mobile phones and send it to a web-based application for analysis and lipmatte color recommendation. The main focus of this methodology is to assess the network performance, particularly regarding client-to-server data transfer and resource loading efficiency under varying device loads. Two testing environments will be conducted using 4, 8, 12, 16, and 20 loads of devices to evaluate the system's scalability and responsiveness.

3.1 System Architecture

The AR system is built using a three-tier architecture, which consists of:

(i) Client Tier (Mobile Devices):

- Users capture lip images using their mobile phones. The lip images are pre-processed before being sent to the web server to reduce data transfer size.
- The mobile device acts as a client, capturing input and sending it to the server for analysis and lipmatte color matching.

(ii) Application Tier (Web Server):

- The web server handles the processing and analysis of the lip images. The image is processed using a lipmatte color recommendation system that matches the detected lip color to a suitable lipmatte shade.
- The server hosts business logic for the recommendation system and manages client requests and responses.

(iii) Data Tier (Database):

- The database stores lip color profiles, user preferences, lipmatte product information, and testing logs.
- The database also logs network performance metrics, such as data transfer rates and response times.

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3.2 Testing Environment and Metrics

To assess the network performance of the system, testing will be conducted using 5 different amount loads of devices: 4, 8, 12, 16, and 20 devices. Each device will simulate real users performing the lip image capture, sending data to the server, and receiving lipmatte color recommendations. The following metrics will be monitored during testing:

(i) Client-to-Server Data Transfer:

- The amount of data transferred between the client and the server during the lip image submission process.

(ii) Resource Loading:

- The time it takes for the server to load and send the lipmatte color recommendation back to the client.
- Server processing time and response time will be tracked to assess how quickly the server can handle requests under different loads.

4. RESULTS AND DISCUSSIONS

This There are two scenarios that has been setup and configure:
Scenario 1: network performance analysis based on client-to-server data transfer.
Scenario 2: network performance analysis based on resource loading from client to server.

4.1 Network Performance

	id	username	full_name	email	password
Edit Copy Delete	1	hanna	hannawahid	hnnawhed16@gmail.com	[illegible]
Edit Copy Delete	4	Farzana	Farzana Huda	farzana123@gmail.com	[illegible]
Edit Copy Delete	5	intan	Intan Zulaikha	intan123@gmail.com	[illegible]
Edit Copy Delete	6	syahirah	Syahirah Ahmad	syerah123@gmail.com	[illegible]
Edit Copy Delete	7	dania	Dania Admin	DaniaAdmin@gmail.com	[illegible]
Edit Copy Delete	8	afrina	afrinaalyani	afrina123@gmail.com	[illegible]
Edit Copy Delete	9	balqis	Nur Balqis	balqis123@gmail.com	[illegible]
Edit Copy Delete	10	jiha	Athira Najiha	jyhae@gmail.com	[illegible]
Edit Copy Delete	11	aina	Aina Dahlan	ainalong@gmail.com	[illegible]
Edit Copy Delete	12	zulfa	Siti Zulfa	zulfaulfa@gmail.com	[illegible]
Edit Copy Delete	13	siti	Siti Khadijah	khadijah05@gmail.com	[illegible]
Edit Copy Delete	14	piqah	Syafiqah	piqah06@gmail.com	[illegible]
Edit Copy Delete	15	ain	ain izzati	aizzati14@gmail.com	[illegible]
Edit Copy Delete	16	atikah	Atikah Jalil	tikah32@gmail.com	[illegible]
Edit Copy Delete	17	hawa	Hawa	hawa24@gmail.com	[illegible]
Edit Copy Delete	18	zulaikha	Zulaikha Nizam	zulaikha31@gmail.com	[illegible]
Edit Copy Delete	19	athirah	Athirah Salahuddin	thirahudin@gmail.com	[illegible]
Edit Copy Delete	20	alani	Alani Fathine	alanfhine@gmail.com	[illegible]
Edit Copy Delete	21	umairah	Umairah Syamsul	mairah18@gmail.com	[illegible]
Edit Copy Delete	22	Syafiq	Syafiq Danial	syfqdnail@gmail.com	[illegible]
Edit Copy Delete	23	huda	farzana huda	huda@gmail.com	[illegible]
Edit Copy Delete	24	far	farzana	far@gmail.com	[illegible]
Edit Copy Delete	25	syahirah	syahirah ahmad	syahirahcomel@gmail.com	[illegible]

Fig. 1. Database of Sign-in User

Fig. 1. illustrates a database sign-in user interface designed to analyze the network performance of distributed computer systems. The analysis is based on network resources and resource loading, within a

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skin tone detector page that uses an image processing method. The database sign-in user is a program that enables users to access a web-based system through augmented reality, recommending lip matte color selections using their credentials. The server then evaluates the user's network performance by analyzing their network resources and resource loading through performance analysis.

4.2 Scenario 1: Network Performance Analysis Based on Client-to-Server Data Transfer

This project focuses on analyzing the network performance of the system's image processing implementation, specifically based on network transfer. Network transfer, or data transfer, refers to the movement of data across a network between devices. This process is essential to network communications and can include various data types, such as files, emails, webpages, and streaming media. Network transfer can occur over local area networks (LANs), wide area networks (WANs), or the internet. Performance analysis evaluates the system by examining the performance of distributed clients (4, 8, 12, 16, and 20) over specific time periods. By analyzing the network performance through data transfer in this project, the testing results will offer valuable insights into the system's efficiency and effectiveness.

Table 1. Network resource between Client to Server

Number Of Device	Network Transfer Test 1	Network Transfer Test 2	Network Transfer Test 3	Average Network Transfer
4	0.29	0.89	0.34	1.29
8	0.54	0.91	0.58	1.64
12	0.79	0.67	0.81	1.73
16	0.82	0.75	1.01	1.90
20	1.14	1.02	0.94	2.47

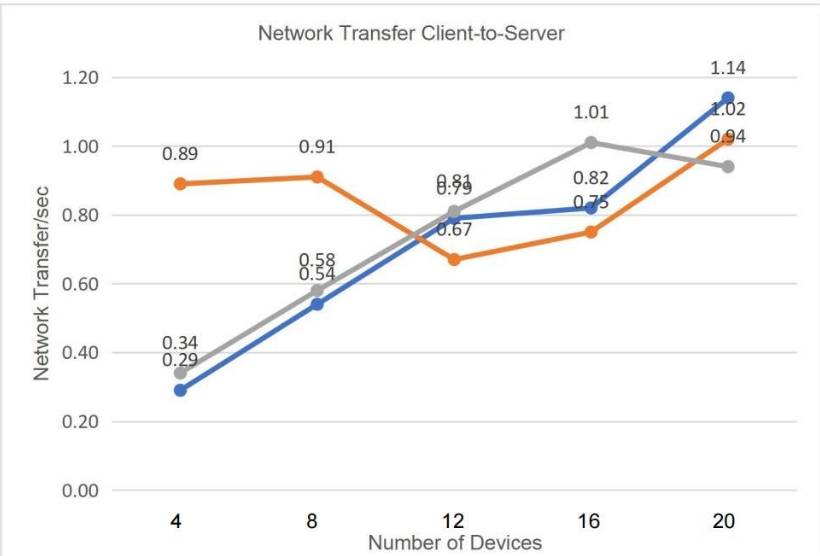

Fig. 2. Network resource between Client to Server

Fig. 2. presents a graph depicting the measurement of network resources between the client and server for various device counts within the network. The figure illustrates the network transfer rate per second for each configuration. Measuring network resources is crucial for evaluating the performance of the client-server image processing technique in a distributed system. A network resource refers to any computer

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resource available to and utilized by other computers on the network. The graph demonstrates a steady increase in the network transfer rate as the number of devices rises. For four devices, the transfer rate is 0.29, and for twenty devices, it reaches 1.14. Although the increase is not strictly linear, the graph shows that as more devices are added, the network can handle larger data flows. Notable increases are seen between 8 and 12 devices (from 0.54 to 0.79) and between 16 and 20 devices (from 0.82 to 1.14), suggesting potential thresholds where the network's capacity utilization becomes more efficient.

These findings are significant for evaluating the scalability and performance of the distributed system based on the client-server model. The results indicate that the network can efficiently handle the image processing workload even as the number of devices grows. This information is valuable for decision-making and capacity planning, ensuring that the network can support future growth and increased traffic without major performance issues. It is also important to consider other factors such as hardware capabilities, network architecture, and application design, which may influence overall network performance.

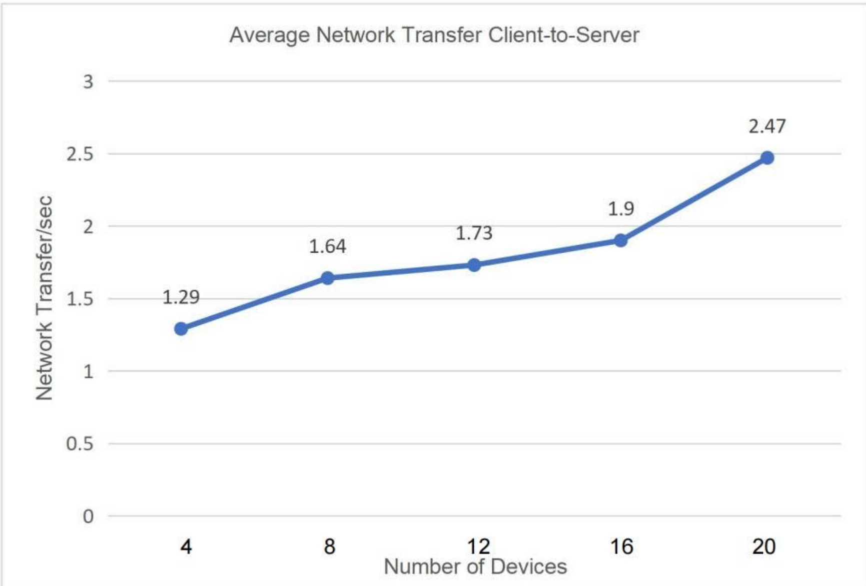

Fig. 3. Average network transfer Client to Server

The second graph in Fig. 3. illustrates the average network transfer rate per second from client to server as the number of devices increases. As shown in Figure 3, the average network transfer rate consistently rises with the number of devices. For four devices, the average transfer rate is 1.29, increasing to 2.47 for twenty devices. Although the increase is not linear, this trend indicates that as more devices are added, the network's overall efficiency improves. Notable jumps in average transfer speed occur at 8 devices (1.64) and 20 devices (2.47). A comparison of the two graphs reveals that both the network transfer rate per second and the average transfer rate per second increase as the number of devices grows. However, the second graph shows a smoother and more uniform rise in average rates, suggesting a more consistent performance improvement across devices. In contrast, the first graph exhibits more detailed fluctuations, which could help identify opportunities for optimization or highlight potential performance bottlenecks.

These results are key to assessing the performance and scalability of the client-server distributed system. They show that even with an increase in the number of devices, the network can efficiently handle the image processing workload. This data is valuable for decision-making and capacity planning, ensuring

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that the network can accommodate future growth and higher traffic without significant performance degradation. It is also essential to consider the potential impact of factors such as hardware capabilities, network architecture, and application design on overall network performance.

4.3 Scenario 2: Network Performance Analysis Based on Resource Loading from Client-to-Server

This project involves evaluating the network performance of the image processing system based on its resource loading. Resource loading refers to the process of retrieving and preparing various resources—such as images, scripts, stylesheets, data files, or other assets—required for a software application, web page, or system to operate properly. Efficient management of these resources is essential in web development, software engineering, and computer systems to ensure smooth functionality. The network performance analysis is conducted by assessing distributed clients (4, 8, 12, 16, and 20) over a specified period. By examining the system's network performance in relation to resource loading, the testing results will provide valuable insights into the system's efficiency and effectiveness, particularly for the detection process.

Table 2. Resource Loading between Client to Server

Number Of Device	Resource Loading Test 1	Resource Loading Test 2	Resource Loading Test 3	Average Resource Loading
4	4.97	2.23	4.07	3.76
8	2.24	2.12	2.95	2.44
12	3.35	3.04	2.09	2.83
16	4.41	3.46	4.01	3.96
20	3.22	2.07	3.12	2.80

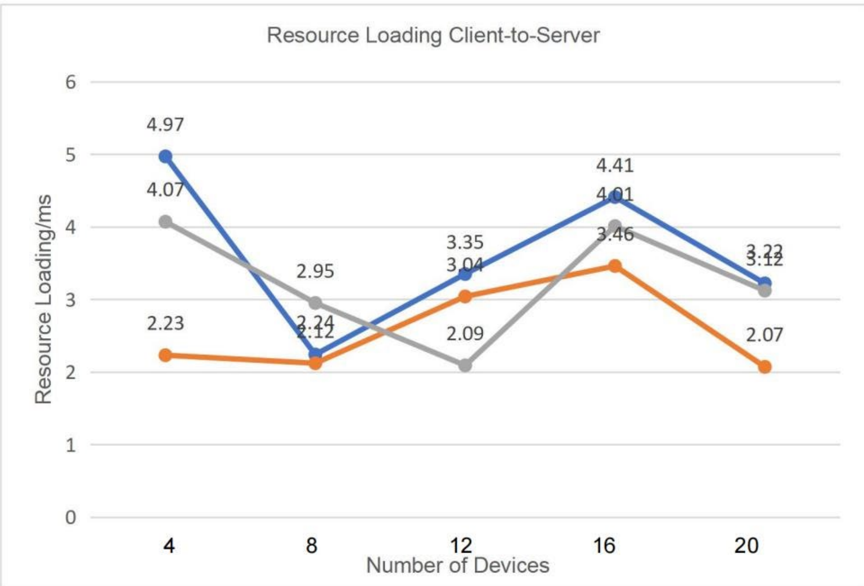

Fig. 4. Resource Loading Client to Server

The graph in Fig. 4. depicts the resource loading times between clients and servers for various device counts in the network. It displays the average resource loading time in milliseconds (ms) for each configuration. Resource loading involves retrieving and preparing scripts, stylesheets, images, and files required for a webpage to function correctly. Efficient resource loading is crucial for optimizing

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performance, reducing costs, and ensuring tasks or projects are completed on time. The graph reveals a clear trend in average resource loading times as the number of devices increases. When there are only 4 devices, the resource loading time is relatively high at 4.97ms, indicating a significant initial overhead or congestion when fewer devices are connected. As the device count increases to 8, the loading time drops significantly to 2.24ms, suggesting improved network efficiency due to better resource allocation and reduced competition among a moderately larger set of devices. However, the loading time rises slightly to 3.35ms with 12 devices, indicating that as more devices compete for resources, network strain begins to manifest. With 16 devices, the loading time peaks at 4.41ms, marking a critical point where resource competition becomes intense, leading to longer loading times. Interestingly, with 20 devices, the loading time decreases again to 3.22ms, showing that the network can adapt and manage the increased demand effectively. This adaptability may be due to dynamic resource allocation algorithms that help maintain stable performance even with a larger number of devices.

In summary, the graph demonstrates that the network can accommodate varying numbers of devices while maintaining acceptable resource loading speeds. Initially, the loading time decreases with the addition of more devices, reflecting efficient resource management. The subsequent fluctuations indicate the network's ability to adjust to varying loads. These findings are vital for evaluating the network's resilience and scalability, ensuring it can handle future growth and increased traffic without significant performance degradation. Additional factors, such as hardware capabilities, network architecture, and application design, should also be considered when assessing overall network performance.

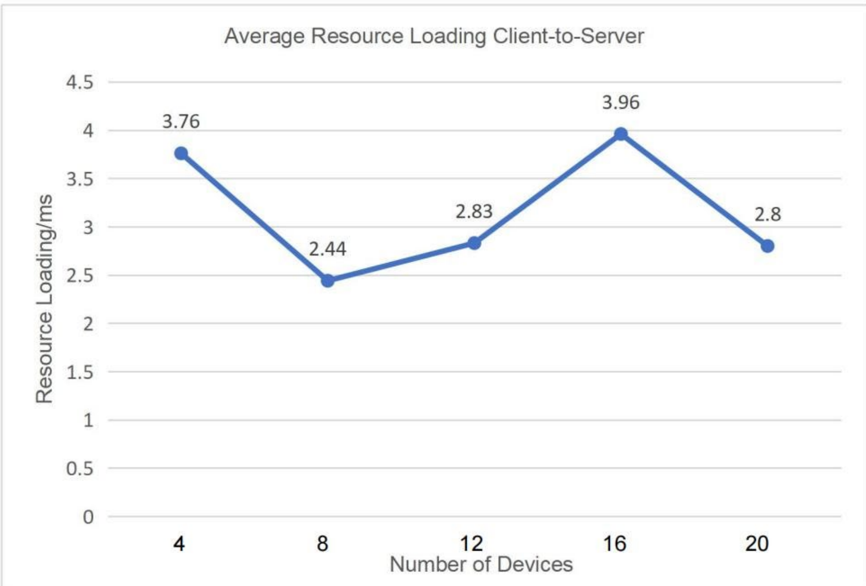

Fig. 5. Average Resource Loading Client to Server

Fig. 5. displays the average resource loading times between clients and servers for varying numbers of networked devices, measured in milliseconds. The graph highlights how resource loading times change as more devices are added, providing insight into the network's performance and efficiency under different loads. Initially, with 4 devices, the average resource loading time is 3.76ms. When the number of devices increases to 8, the loading time drops significantly to 2.44ms, suggesting the network operates more efficiently with minimal conflict and optimized resource allocation. However, as the device count reaches 12, the resource loading time rises slightly to 2.83ms, indicating a small increase in latency as more devices compete for limited resources. At 16 devices, the average resource loading time peaks at 3.96ms, marking

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a point where heightened competition for network resources leads to slower loading times. Despite this, when the number of devices increases to 20, the loading time decreases again to 2.80ms, indicating that the network successfully adapts to the added load. This flexibility may be attributed to dynamic resource allocation algorithms that help maintain consistent performance as the number of devices grows.

In conclusion, the analysis of the graph shows that the network can accommodate different numbers of devices while maintaining reasonable resource loading times. The initial decrease in loading time reflects effective resource management as devices are added. The fluctuations that follow demonstrate the network's adaptability in responding to varying loads. These findings are essential for evaluating the network's resilience and scalability, ensuring it can handle future growth and higher traffic without significant performance degradation. Additionally, factors such as hardware capabilities, application architecture, and network topology should be considered to gain a comprehensive understanding of the network's performance.

5. CONCLUSION AND RECOMMENDATION

In conclusion, the exploration of AR technology, particularly in the beauty industry, highlights its transformative potential in enhancing user engagement and streamlining the shopping experience. The dual analysis of network performance—focusing on client-to-server data transfer and resource loading—reveals the critical importance of a robust network infrastructure to ensure seamless AR interactions. This study underscores that low latency and high bandwidth are paramount for optimal user experiences in web-based AR systems, such as virtual lipstick color recommendation tools. The results demonstrate a clear correlation between the number of devices and network performance, with findings indicating that as user load increases, the network adapts and effectively manages resource allocation. While initial loading times may spike under heavier loads, the network's ability to reduce loading times at maximum capacity suggests a sophisticated underlying architecture capable of managing complex demands.

Looking to the future, further research should expand on several critical areas. Firstly, investigating the implementation of more advanced dynamic resource allocation algorithms could yield insights into optimizing network performance under variable loads. Additionally, exploring the impact of emerging technologies, such as 5G connectivity and edge computing, could significantly enhance real-time AR applications by minimizing latency and improving overall user experience. Further user-centric studies focusing on diverse demographic groups could provide a more comprehensive understanding of user interactions with AR in retail environments. Finally, examining the long-term effects of AR technology on consumer behavior and brand loyalty in the beauty sector could offer valuable perspectives for both practitioners and researchers, ensuring that AR applications not only meet current market demands but also pave the way for future innovations in the industry.

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7. CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

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8. AUTHORS' CONTRIBUTIONS

Zulfikri Paidi: Conceptualisation, methodology, formal analysis, and supervision; **Nurhanna Md Abd Wahid**: Conceptualisation, methodology, formal analysis, investigation and writing-original draft; **Nurzaid Muhd Zain**: Formal analysis, writing-review and editing, and validation; **Mahfudzah Othman**: Writing- review and editing, and validation.

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