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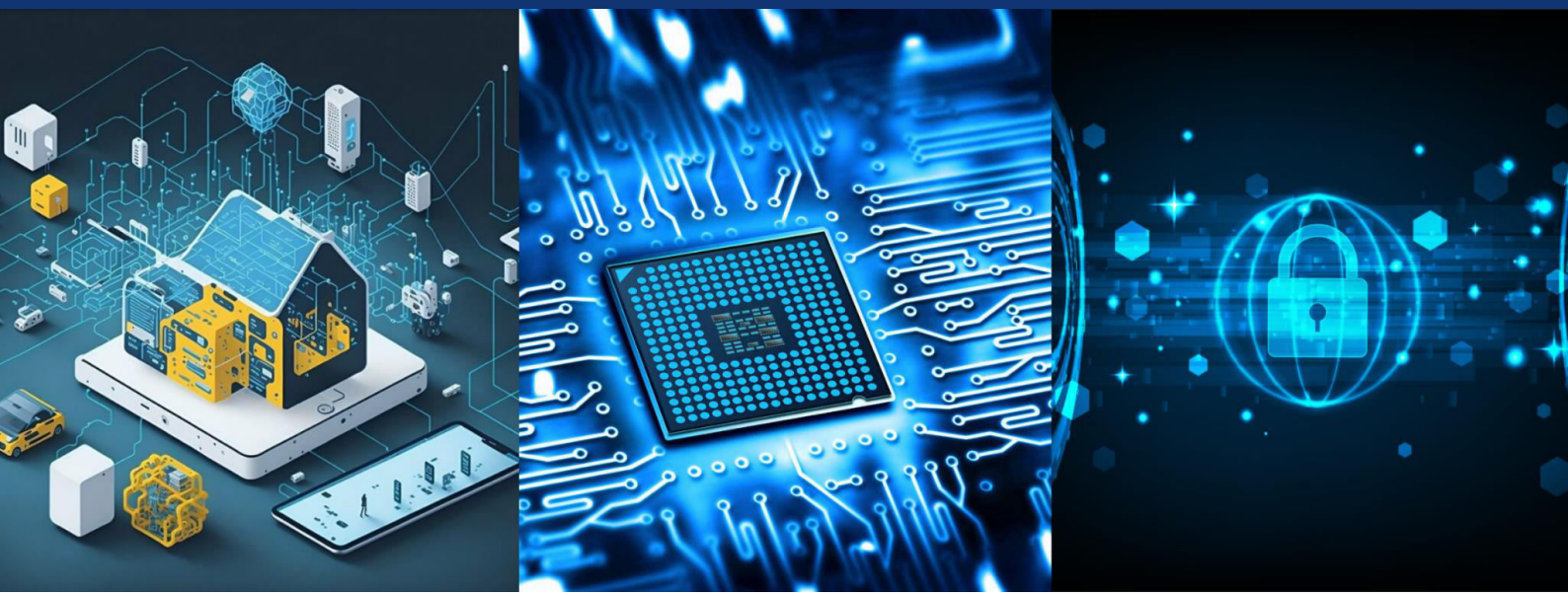

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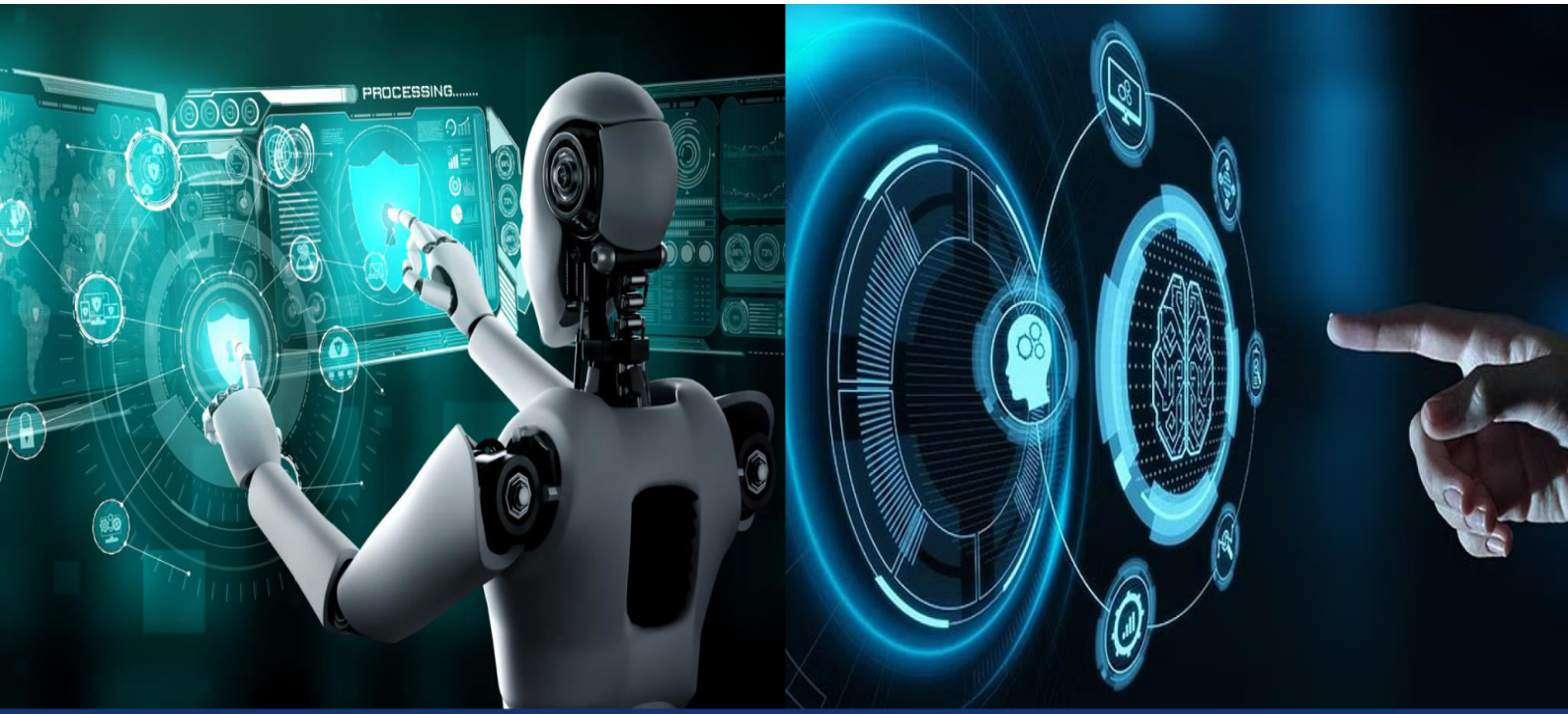

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Design and Development of an Online Streaming Platform using the MERN Stack

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ABSTRACT: Mobile video streaming drives the rapid growth of mobile Internet traffic, and the cache threshold plays a vital role in regulating device downloading behaviour. Static cache configurations in Android OS fail to balance unconsumed content cost and user experience, leading to over 40% cost reduction and nearly 30% reduction in freezing durations in low-bandwidth environments with the Smart Cache with Adaptive Thresholding (SCAT) algorithm. Future wireless networks aim for high-bandwidth, low-latency connectivity, with edge caching, computing, and communication (edge-C3) enhancing network utilization for video streaming applications. This paper proposes a new taxonomy for video edge-C3 and discusses state-of-the-art solutions and challenges for next-generation mobile networks.The Chat Box bridges communication gaps between sign language users and non-users, improving accuracy and responsiveness. For user-generated content (UGC) videos, a content-adaptive rate control method reduces bit-rate errors and BD-Rate by up to 1.99%.AI-powered recommendation engines combining collaborative filtering with neural networks outperform traditional methods in user satisfaction and scalability [5]. In competitive markets, AI-driven recommendation strategies optimize platform decision-making and prices [6]. The integration of AI in SEO strategies revolutionizes website optimization and traffic [7]. Collaborative playlists in music streaming platforms are enhanced by user insights into features such as multiple collaborators and communication capabilities [8]. Live streaming's socio-technological impact in China reveals the importance of engagement and interaction mechanisms [9], while P2P live streaming systems face challenges in handling flash crowds without admission control [11]. Reinforcement learning-based control schemes improve system stability and learning efficiency [12]. Smart grid privacy protection through power management models ensures appliance usage data privacy [16].

KEYWORDS: Online Streaming Platform, MERN Stack, Real-Time Chat, User-Generated Content, AI-Powered Search, Personalized Recommendations, Live Streaming, Video Processing, Playlist Management, Reward System, Gamification, Content Moderation, Privacy and Security, WebRTC, Scalable Architecture.

I. INTRODUCTION

In recent years, the prevalence of mobile devices leads to the rapid growth of the mobile Internet traffic. Cisco reported in that the global mobile data traffic has increased Manuscript received March 25, 2015; revised June 18, 2015; accepted July 23, 2015. Date of publication September 17, 2015; date of current version December 5, 2015. This work was supported in part by the National Science Foundation of China under Grant 61272397, Grant 61174152, and Grant 61331008, in part by the Guangdong Natural Science Funds for Distinguished Young Scholar under Grant S20120011187, in part by the Basic Research Program 973 of China under Grant 2011CB302505, and in part by the Innovation Team from Guangdong Scientific Bureau, China, under Grant 201001D0104726115 [1].The global mobile traffic is expected to grow about eight times by the year 2022, where video data will account for about 80% of the traffic. This is not surprising, given that about 60% of the worldwide population has watched videos on their mobile devices in 2018[2].

With the rapid growth of mobile devices and platforms like YouTube, TikTok, and BiliBili, user-generated content (UGC) videos have become widespread, leading to an explosion in data volume and new challenges for video compression. While advancements like HEVC and VVC have improved video coding, rate control (RC) technologies are critical, especially in bandwidth-limited scenarios.[4] Traditional RC methods, designed for professionally generated content (PGC), often fail with UGC videos due to their unique characteristics, including poor quality, editing effects, and temporal variations. These characteristics lead to increased bit-rate errors and inefficient compression.[4]

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To address this, we propose a content-adaptive RC method tailored to UGC videos, including a picture-level RC method, an SVM-based classifier for temporal variations, and a bit allocation refinement technique. Our approach improves compression performance, achieving BD-Rate savings and reducing bit-rate errors compared to traditional methods [4].

Neural network-based algorithms complement this by modelling complex patterns and improving accuracy. Combining both approaches creates a powerful hybrid model that enhances recommendations by integrating additional data. This paper explores the synergy between these techniques to improve recommendation engine performance and user experiences [5].

The growth of e-commerce platforms has led to increased use of recommendation systems to enhance shopping experiences and drive sales. This paper explores how e-commerce platforms use recommendations in competitive markets, focusing on duopoly manufacturers under agency contracts. It develops a game model to analyse how commission rates and competition affect manufacturers' pricing and the platform's recommendation strategies. Three strategies are examined: no recommendation, exclusive recommendation, and non-exclusive recommendation. The findings suggest that recommendation services are most effective with higher commission rates and that the platform's strategy depends on market competition. This study offers insights into the interplay between platforms, manufacturers, and recommendations [6]. Marketing has evolved significantly with the integration of technology, particularly Artificial Intelligence (AI), which is transforming how businesses approach strategies and tactics. AI, which enables machines to perform tasks that typically require human intelligence, has been increasingly applied in digital marketing to enhance customer engagement, personalize user experiences, and optimize content. AI technologies like machine learning, natural language processing, and computer vision are enabling businesses to better understand consumer behaviour, preferences, and needs, allowing for more targeted marketing efforts. As a result, e-commerce platforms are using AI to optimize SEO, improve search engine rankings, and increase web traffic. Additionally, AI-powered analytics help companies tailor their marketing messages and offerings, boosting customer loyalty and satisfaction. With the growing importance of AI, businesses are investing more in digital strategies to stay competitive in the ever-evolving e-commerce landscape [7]. Music co-curation, especially through collaborative playlists (CPs), has a long history, evolving from jukeboxes and mixtapes to today's digital platforms. CPs, which allow multiple users to create and edit playlists together, are offered by streaming platforms like Spotify, Deezer, and YouTube. Despite their popularity, with 58-80% of Spotify users reportedly engaging with CPs, research on their usage is limited compared to personal playlists. The COVID-19 pandemic further highlighted the need for virtual social music experiences, making CPs more relevant. This study focuses on user perceptions of CPs, exploring what users find useful and what they feel is lacking. By analysing responses from 70 Spotify users, the study identified eight critical factors influencing CP usage, providing valuable insights for designing better CP platforms and advancing research in music information retrieval and human-computer interaction [8].

The rise of mobile devices with high-definition cameras and fast internet has led to a boom in live streaming. Platforms like Twitch.tv allow individuals to share experiences and host shows. While live streaming is mainstream in North America, China has a larger, more diverse live streaming culture. This study explores why live streaming in China is so engaging [9]. Our research includes surveys and interviews with Chinese users, revealing a strong interest in personal experiences of strangers rather than friends or events. Reward systems and fan communities on messaging apps foster social interaction. These insights aim to guide future platform designs for live streaming [9]

BACKGROUND AND RELATED WORK

We start with an overview of live streaming in China and then review related studies on vloggers, video game streaming, and general live streaming [9].

YouTube and Vloggers: YouTube has helped vloggers share personal content, with research focused on the impact of vlogging on self-awareness. This study looks at live streaming, which is more interactive and real-time [9].

Video Game Live Streaming (on Twitch.tv): Video game streaming forms tight-knit communities. Studies have explored why viewers watch games for entertainment and social integration. This research extends beyond gaming to include diverse live streaming content [9].

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General Live Streaming: Studies of early mobile platforms like Bambusa and Periscope reveal varying motivations for streaming, including social interaction and branding. These insights help explain general live streaming but do not focus on the Chinese context [9]. This paper aims to understand live streaming in China, where daily active users and professional streamers outnumber other regions, offering insights that differ from Western trends [10]. Applying PPO to control problems like the cart-pole inverted pendulum faces two challenges: instability during learning and reward system design. To address instability, we propose an Adjustable Policy Learning Rate (APLR) that adjusts the learning rate based on expected advantages. A reward system combining Lyapunov stability and fuzzy inference (FIS) is used to guide learning using control theory and system knowledge [12]. The rest of the brief discusses PPO, FIS, the proposed APLR and Lyapunov-fuzzy reward system, and simulation results [12]. Mobile Location-Based Services (MLBSs) have gained popularity, but face issues such as limited rewards, security risks, and privacy concerns. This paper introduces **Loca Ward**, a secure and privacy-preserving MLBS that allows users to earn rewards by visiting participating locations. Users receive anonymous tokens that can be redeemed across different stores without revealing their identity or location history. The system ensures privacy and security through pseudonyms and token verification, and is resilient to attacks. A testbed implementation shows its efficiency in computation, communication, and storage [13].

Smart grids aim to enhance energy efficiency, reduce costs, and meet environmental goals like the EU's 20-20-20 targets. They differ from legacy grids by using a two-way communication network for real-time optimization, such as load management and distributed energy storage. Advanced Metering Infrastructure (AMI) plays a key role, with smart meters measuring and transmitting detailed energy usage data. However, the security and privacy of this data are critical concerns, as unauthorized access could expose private activities. This paper proposes a method to protect privacy by moderating load signatures through energy mixing with rechargeable batteries, addressing the privacy challenges in smart grids. We introduce a privacy moderation algorithm and evaluate it using several methods, showing that it can significantly enhance privacy with feasible battery sizes [16].

Online social networking (OSN) sites, like Facebook, have seen rapid global growth, with millions of active users. These platforms allow people to share digital content, stay in touch with others, and create personal profiles. The growth of OSN sites presents business opportunities, especially for understanding why users continue to engage with these platforms. However, despite initial success, some OSN sites have experienced fluctuations in usage, making it critical to understand what influences users' continued participation [17].

Social media platforms allow users to share opinions, communicate, and discover trends but also foster uncivil behaviour and misinformation. Uncivil behaviour, such as harassment, leads to anxiety and depression, while misinformation disrupts health, democracy, and security. Despite these challenges, content moderation practices vary widely, with some platforms enforcing strict rules and others offering minimal moderation. This paper investigates content moderation through two research questions: (1) How is content moderation studied, and what gaps exist? (2) How do platforms define, implement, and enforce moderation policies? By analysing various research papers and practices across multiple platforms, we categorize moderation policies, content types, and community guidelines, identifying inconsistencies and research gaps. Our findings aim to help researchers and companies develop more transparent and inclusive moderation processes [18].

Mobile video streaming has attracted considerable research due to the rapid adoption of mobile devices. Studies have measured traffic characteristics, energy consumption, and user behaviour, revealing issues like frequent interruptions during video viewing. Research on streaming protocols aims to improve user experience and resource utilization, with proposals for energy-efficient streaming and cross-layer optimization [1]. Building on previous work, our research focuses on cost-effective mobile video streaming. We propose SCAT, a simple approach to adjust cache thresholds dynamically, improving video streaming efficiency without altering buffer management. SCAT is implemented on an Android platform and evaluated in a real testbed [1].

A. R-Q Based Methods

R-Q methods analyse the relationship between bit-rate and quantization parameter (QP). Early work developed quadratic models to relate bit-rate and distortion, while later approaches incorporated the mean absolute difference (MAD) to account for video complexity. However, challenges arose from the interdependence of QP and MAD,

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leading to the "chicken and egg" dilemma. To address this, some models used hyperbolic curves to describe the relationship between bit-rate and distortion. Further work refined these models, exploring non-linear relationships and introducing alternative methods to improve coding efficiency. Recent advancements have led to notable coding gains in video encoders like VVC. [4].

B: R-ρ

Based methods model the relationship between bit-rate and the percentage of zeros among quantized transform coefficients (denoted as ρ). He et al. identified a linear correlation between bit-rate and ρ, leading to a new frame-level rate control method in AVC that models the relationships between bit-rate, QP, and ρ. Empirical observations suggest that higher QP increases Qstep, which in turn raises ρ. Therefore, R-ρ approaches are conceptually similar to R-Q methods, focusing on the impact of ρ on bit-rate control.[4].

C. R-λ Based Methods

R-λ based methods address the "chicken and egg" problem by directly linking bit-rate and λ, providing more accurate rate control and improved coding performance over R-Q and R-ρ methods. In HEVC, initial parameters were empirically set, with updates based on actual bit-rate and λ. Later, recursive Taylor expansion (RTE) and human eye perception-guided updates further improved efficiency. However, these methods struggle with user-generated content (UGC) videos due to their complex characteristics. To overcome this, picture-level RC methods specifically designed for UGC videos are being developed to improve performance and reduce bit-rate errors [4].

Research on flash crowds in Web services and P2P file-sharing systems exists, but the performance of P2P live streaming systems under flash crowds remains understudied. This work explores this gap in P2P file-sharing, website access, and live streaming systems [11. P2P live streaming systems can be tree-based or mesh-based. Mesh-based systems are more adaptive during flash crowds due to their flexible topologies, and our analysis applies to both types, assuming proper management [11]. Non-intrusive appliance load monitors (NALM) track appliance usage patterns through metered energy data processing, enabling identification of individual appliance use even when multiple power signatures are aggregated. In the future, with intervals like 15 minutes, it could be possible to determine when and how specific appliances are operated [16]. The European Data Protection Directive aims to protect privacy by limiting the use of personal data to specific purposes. However, the scope of protection is reduced by exceptions for national security, law enforcement, and other factors, limiting the effectiveness of these safeguards. [16]. This paper proposes a privacy protection method for smart metering systems by managing energy usage within the home, before sensitive data is collected. This method provides an additional layer of privacy and complements existing solutions, enhancing overall protection [16].

II. METHODOLOGY

We built a testbed for our experiments, consisting of a mobile device, laptop with WiFi, and a router for Internet access. The HTC G8 smartphone, running Android OS, was used for testing, with YouKu as the default video streaming app due to its popularity in China. The streaming rate was set to 300 Kbps, and we evaluated video quality measures such as freezing duration and unconsumed content [1]. The laptop acted as a wireless router using Access Point mode, connecting to the smartphone for Internet access. DummyNet and ipfw were used to simulate network conditions, while Wireshark captured packet-level traces [1]. The system sends and receives sign language images in .bmp format via TFT LCD touch shields and Arduino Mega 2560 Rev3 using RX-TX serial communication. The Chat Box enables two-way communication, beginning with tapping to select words, followed by decision-making to either ignore or reply. Ignoring ends the process, while replying continues the loop until the user decides to end it [3]. This study explores live streaming practices in China, focusing on four research questions: motivations and practices for watching and conducting live streams, interactions between viewers and streamers, mechanisms for rewarding streamers, and factors contributing to viewer engagement [9].

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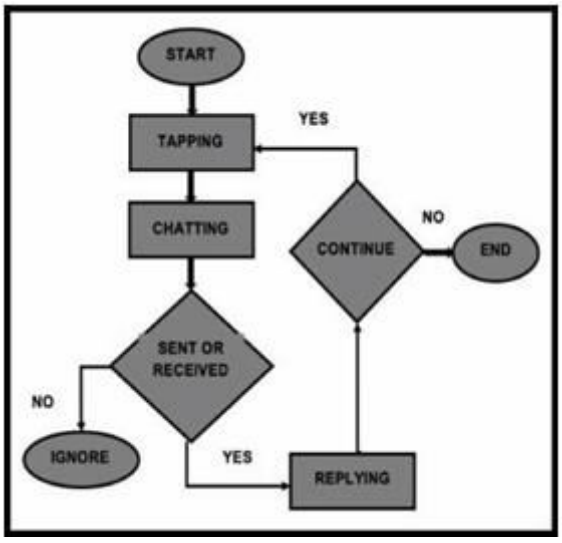

Fig.1. Presents the System Flowchart showing the internal logic of the entire system, thus providing the backbone on how the project works from start to end.

The survey included closed-ended questions about live streaming experiences, including viewer and streamer roles, frequency of streaming, and features that attract viewers. These questions were adapted from prior studies on live streaming and user engagement [9].

We recruited participants using SoJump.com to ensure diversity and avoid platform bias. The survey was active for two weeks in July 2017, with 902 completed surveys, 375 of which were removed due to various reasons. The final dataset contained 527 responses, and participants received a cash reward for completing the survey [9]. Economical sremuneration is commonly used as an incentive to encourage honest behaviours in blockchain systems. Building a sustainable economic reward system in Ethereum requires significant effort, leveraging game theory principles [14].

A. Execution Layer's Block Proposal Rewards

Interacting with the Ethereum Execution Laer (EL) requires Gas payment for transaction inclusion. EIP 1559, introduced in the London Hard Fork, divides the fees into three components: Gas Limit, Base Fee per Gas, and Priority Fee per Gas. Block proposers now only receive the aggregation of Gas Tips, as base fees are burned [14].

B. Characterization of Attestation Rewards

Validators participate in the consensus system by voting on blocks. Attestation rewards are earned based on the weight of specific flags, such as Source, Target, and Beacon block root. After the Altair Hard Fork, these rewards are calculated using formulas based on effective balance and total active balance [14].

C. Characterization of Sync Committees Rewards

Sync committees, introduced in the Altair Hard Fork, consist of 512 randomly selected validators who sign new block headers. Validators receive sync committee rewards after every slot they participate in. These rewards are updated at the state transition of every slot, and penalties apply for missed duties [14].

D. Characterization of Block Proposals

Block proposers, chosen randomly each epoch, earn rewards from including attestation aggregations and sync aggregates in the block. These rewards are sporadic but substantial, reflecting the randomness of the proposer election process [14].

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E. Validators' Penalizations

Validators who fail to meet their duties or act in a way that undermines the network face penalties. These penalties are designed to incentivize compliance and protect the network's finality. Missing duties, such as missing block proposals or sync committee participation, result in balance deductions [14].

F. Maximum Extractable Reward (MER)

The Maximum Extractable Reward (MER) refers to the theoretical maximum reward a validator could achieve in an epoch, calculated based on optimal performance. The difference between the MER and actual rewards reflects the validator's performance quality in their duties [14]. This research aims to leverage TRA to enhance understanding of continuance intention predictors. While attitude and subjective norm are included, we add trust beliefs, habit, privacy restrictiveness, and site experience to enrich TRA and focus on OSN continuance intention [17].

Attitude and Subjective Norm : Attitude toward continued use of an OSN site influences continuance intention, with positive attitudes leading to stronger intentions. While evidence is mixed, attitude is especially relevant in voluntary use contexts and has recently been linked to OSN usage intention [17].

Trusting Beliefs and Habit: Trusting beliefs directly affect continuance intention, helping reduce perceived risks associated with OSNs. These beliefs are particularly significant in contexts involving privacy and security risks [17]. Habit is another critical factor, as habitual behaviour often leads to automatic intention. In OSN use, habit can drive continuance intention through automatic processing, with evidence suggesting frequent usage due to habit [17].

Privacy Restrictiveness Moderator: Privacy restrictiveness moderates the relationship between trusting beliefs and continuance intention. Users with higher privacy control feel more secure, and trusting beliefs are less crucial in these cases. In contrast, users with less control may rely more on trust to mitigate perceived risks [17].

Site Experience Moderator: Experience with a site reduces ambiguity and strengthens trusting beliefs, potentially lessening the influence of trust on continuance intention over time. Prior research suggests that experience moderates the effect of trust on behavioural intentions [17]. This version is condensed while maintaining key information, with references added as per your request.

III. RESULTS AND DISCUSSION

This study presents an innovative Online Streaming Platform using the MERN stack, designed to integrate real-time user interaction, AI-powered content management, and personalized recommendations. The platform includes key features such as genre-based chat groups, user-generated content (UGC) creation, personalized recommendations, and live streaming capabilities. Each feature leverages a combination of cutting-edge algorithms and technologies to provide an engaging and interactive user experience.

A. Key Features and Contributions

1. Chat Box with Genre-Based Groups: The platform allows users to engage in real-time messaging within genre-based groups, fostering a community-driven environment.

2. User-Generated Content (UGC): One of the core features of the platform is its support for UGC, allowing users to upload and edit short videos.

3. AI-Powered Search and Recommendations: The platform leverages AI algorithms, including

CNNs (ResNet), Collaborative Filtering, and Natural Language Processing (NLP), to deliver a personalized search and recommendation system. By analysing user preferences and viewing history, the platform suggests content tailored to individual tastes. This feature operates in the cloud to ensure scalability and efficiency, particularly as user data grows over time.

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Users can create and share playlists of their favourite content, which are integrated into their profiles. Basic CRUD (Create, Read, Update, Delete) operations support playlist management, allowing users to personalize their content experience. This functionality is available both locally and, in the cloud, ensuring accessibility and synchronization across devices.

The live streaming feature enables users to go live and interact with their audience in real-time. Using WebRTC and HLS (HTTP Live Streaming), the platform supports adaptive streaming for optimal video quality and performance. This real-time interaction is vital for fostering a dynamic user experience and engagement, with the streaming functionality available in both local and cloud environments.

4. Reward System: A gamified reward system incentivizes users to engage more with the platform by awarding badges and points for activities such as liking, sharing, and viewing content.

5. Privacy and Moderation: To ensure privacy and content moderation, the platform incorporates. A custom CNN-based face detector, along with Haar cascade classifiers, is used to anonymize faces in uploaded videos. This functionality is vital for maintaining a safe and respectful environment for all users, supporting both local and cloud-based operations for better scalability and performance.

IV. ANALYSIS AND DISCUSSION

The integration of real-time interaction features, AI-powered content management, and robust privacy measures demonstrates the platform's potential to revolutionize online streaming experiences. Each feature contributes to user engagement and satisfaction, with a strong emphasis on personalization and security.

Technological Contributions: The platform's use of WebSocket, Firebase, MQTT, FFmpeg, CNNs, and WebRTC showcases a comprehensive approach to building a modern online streaming system. These technologies ensure smooth performance and scalability, catering to a diverse range of user needs, from content creation to real-time communication.

User Experience: Features like genre-based chat boxes, live streaming, and personalized recommendations foster an interactive, user-centric environment. By integrating user feedback and content preferences, the platform enhances its adaptability to different audience types and viewing behaviours.

Privacy and Security: The inclusion of AI-driven privacy measures, such as face anonymization, ensures that users can engage with the platform securely, reducing concerns over personal data leakage.
Cloud and Local Integration: The dual deployment approach, combining both local and cloud-based solutions, provides a flexible and scalable architecture.

V. CONCLUSION

The Online Streaming Platform Using the MERN Stack successfully integrates cutting-edge technologies and AI-driven features to provide an interactive and personalized user experience. By leveraging WebSocket, Firebase, WebRTC, CNNs, and various other tools, the platform supports key functionalities such as real-time messaging, personalized recommendations, live streaming, and user-generated content

The implementation of privacy measures, including AI-powered face anonymization and content moderation, ensures a secure environment for users, while the gamification features incentivize increased engagement and retention. The use of both local and cloud-based solutions provides scalability and flexibility, allowing the platform to efficiently handle growing user demands.
In conclusion, this project showcases the potential of the MERN stack in creating a modern, feature-rich online streaming platform that can cater to a diverse and evolving audience. Future developments, such as further AI optimization and integration of immersive technologies like VR/AR, will enhance user engagement and solidify the platform's position as a leading contender in the online streaming market.

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Feature Analysis for Video Streaming App

Feature	Contribution(s)	Algorithms for Analytics	Local	Edge	Cloud
Chat Box with Genre-Based Groups	Real-time messaging and group creation based on genres for user interaction	WebSocket, Firebase, MQTT	✓	✓	✓
User-Generated Content (UGC)	Users can create and upload short videos, such as acting or mimicry; includes basic video editing and processing	FFmpeg for editing, CNN for content analytics	✓	✓	✓
AI-Powered Search and Recommendations	Personalized search and recommendation system based on user preferences and viewing history	CNNs(ResNet), Collaborative Filtering, NLP models		✓	✓
Playlist Creation and Sharing	Users can create and share playlists of favourite content, integrated into their profiles	Basic CRUD operations for playlist management	✓	✓	
Live Streaming	Enable users to go live, stream in real-time, and interact with their audience	WebRTC, HLS for adaptive streaming	✓	✓	✓
Reward System	Gamification and user incentives (e.g., badges, points) based on engagement, likes, and shares	Points calculation logic, potentially blockchain			✓
Privacy and Moderation	AI-powered face anonymization, moderation of user-generated content to prevent inappropriate content	Haar cascade, Custom CNN-based face detector	✓	✓	✓

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