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Decentralized Edge Computing Frameworks for Global Cloud Based Broadcasting Systems

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ABSTRACT

The rapid growth of global cloud-based broadcasting systems has increased the demand for efficient data processing and low-latency content delivery. However, many community-based broadcasting initiatives still rely on centralized cloud infrastructures, which often cause latency issues, limited scalability, and high bandwidth consumption. In the context of community digital empowerment, integrating decentralized edge computing frameworks offers an opportunity to improve broadcasting performance while strengthening community technological capacity. **This community service** research aims to design and implement a decentralized edge computing framework to support global cloud-based broadcasting systems while enhancing community understanding and utilization of distributed computing technologies. **Program applied** a participatory community service approach consisting of needs assessment, system design, training workshops, and implementation. Community participants and local digital media practitioners were introduced to decentralized edge computing concepts, followed by hands-on training in deploying edge nodes and integrating them with cloud broadcasting platforms. **Implementation demonstrated** improved broadcasting efficiency with reduced latency and optimized bandwidth utilization. Participants also showed increased technical competence in managing decentralized infrastructure and operating cloud-assisted broadcasting services. **Decentralized edge** computing framework effectively supports scalable broadcasting systems while empowering communities with practical digital infrastructure skills. This approach contributes to sustainable digital transformation and provides a replicable model for community-based broadcasting development.

1. INTRODUCTION

The rapid expansion of digital communication technologies has significantly transformed global broadcasting systems, enabling content distribution across diverse geographic regions through cloud-based infrastructures. In recent years, cloud computing has become a fundamental platform for media streaming, digital broadcasting, and real time communication services due to its scalability, accessibility, and cost efficiency [1]. However, the increasing demand for high-quality and low-latency broadcasting has exposed several limitations of centralized cloud architectures, particularly in community based or small-scale broadcasting environments. High network latency, bandwidth congestion, and dependency on distant data centers often reduce the effectiveness of broadcasting services, especially in developing regions where digital infrastructure is still evolving [2]. These challenges highlight the need for innovative technological approaches that can improve broadcasting efficiency while remaining accessible to local communities.

One promising solution is the integration of decentralized edge computing frameworks within cloud-based broadcasting systems [3]. Edge computing enables data processing closer to the data source by utilizing distributed computing nodes located near end users, thereby reducing latency and optimizing network performance. By decentralizing processing tasks from centralized cloud servers to edge nodes, broadcasting systems can achieve more efficient data delivery, improved scalability, and enhanced service reliability [4]. In the context of community empowerment, the adoption of edge computing technologies also presents an opportunity to improve digital literacy and technological capability among local broadcasting practitioners. Through community engagement and knowledge transfer, decentralized infrastructures can be implemented not only as technological solutions but also as educational tools that strengthen local digital ecosystems [5].

This community service research aims to design and implement a decentralized edge computing framework to support global cloud-based broadcasting systems while improving the technological capacity of community participants. The program focuses on introducing practical knowledge related to distributed computing, edge node deployment, and integration with cloud broadcasting platforms [6]. Through training sessions, workshops, and hands-on implementation, community members are encouraged to actively participate in the development and operation of decentralized broadcasting infrastructures. Such participatory approaches are essential to ensure that technological solutions are sustainable, applicable, and adaptable within community environments [7].

Furthermore, this initiative aligns with several Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education), which emphasizes inclusive and equitable access to knowledge and digital skills. SDG 9 (Industry, Innovation, and Infrastructure), which promotes resilient digital infrastructure and technological innovation; and SDG 17. Partnerships for the Goals, which highlights collaborative efforts between academic institutions, communities, and technological practitioners [8]. By integrating decentralized edge computing with community engagement, this research contributes not only to technological advancement in broadcasting systems but also to broader efforts in supporting sustainable digital transformation and community-based innovation.

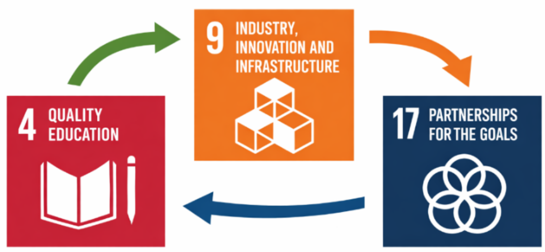

Figure 1. Sustainable Development Goals (SDGs) related to digital infrastructure and community empowerment

The Figure 1 SDGS that are closely related to this initiative include SDG 4 (Quality Education), which emphasizes improving digital literacy and technological competencies SDG 9 (Industry, Innovation, and Infrastructure), which promotes the development of resilient digital infrastructure and technological innovation and SDG 17 (Partnerships for the Goals), which highlights the importance of collaboration between academic institutions, communities, and industry partners in supporting sustainable technological development [9].

Therefore, this community service research aims to design and implement a decentralized edge computing framework to support global cloud-based broadcasting systems while enhancing community technological capacity [10]. The program focuses on introducing distributed computing concepts, providing hands-on training on edge node deployment, and integrating decentralized infrastructure with cloud broadcasting platforms. Through participatory engagement and knowledge transfer, this initiative seeks to improve broadcasting efficiency while empowering communities to actively participate in the development and management of digital broadcasting technologies [11].

2. LITERATURE REVIEW

The rapid development of information and communication technology has significantly influenced the evolution of digital broadcasting systems. The integration of internet-based platforms with cloud computing infrastructure has enabled broadcasters to deliver multimedia content to global audiences efficiently [12]. In modern broadcasting environments, digital media platforms require systems capable of handling large volumes of data, supporting real-time processing, and ensuring seamless content delivery across different geographical regions. As the demand for high-quality streaming services continues to grow, broadcasting systems must adopt advanced computing technologies that provide scalability, reliability, and low-latency performance [13].

However, traditional centralized broadcasting infrastructures often struggle to handle increasing network traffic and real-time service demands. These limitations highlight the importance of adopting distributed computing approaches such as edge computing and decentralized frameworks [14]. By distributing computational resources across multiple nodes within a network, broadcasting systems can improve data processing efficiency while reducing latency and bandwidth consumption. Therefore, understanding the technological foundations of cloud computing, decentralized systems, and community based digital broadcasting is essential for developing innovative solutions that support sustainable digital communication infrastructures [15].

2.1. Cloud-Based Broadcasting Systems

Cloud-based broadcasting systems have become a widely adopted solution for managing and distributing digital media content in modern broadcasting environments [16]. By utilizing cloud computing platforms, broadcasters can store large volumes of multimedia data, perform video processing, and distribute streaming content to users across different geographical locations [17]. Cloud infrastructures offer several advantages, including scalability, flexibility, and cost efficiency, which allow organizations to adjust computing resources based on broadcasting demands. As a result, many digital media platforms rely on cloud services to support live streaming, video on demand services, and multimedia distribution [18].

Despite these benefits, cloud-based broadcasting systems also face several challenges related to centralized architecture. When data processing occurs exclusively in distant cloud data centers, users may experience increased latency and slower content delivery, particularly in real-time broadcasting scenarios [19]. Network congestion and bandwidth limitations can further degrade streaming quality, especially during peak usage periods. These challenges have encouraged researchers and technology practitioners to explore hybrid computing architectures that combine cloud infrastructure with distributed computing technologies to improve system efficiency and reliability [20].

2.2. Edge Computing and Decentralized Computing Frameworks

Edge computing is a distributed computing paradigm designed to process data closer to its source rather than relying entirely on centralized cloud servers. By placing computing resources near end users or data-generating devices, edge computing reduces the distance that data must travel across the network [21]. This approach significantly improves system response time and reduces network congestion, making it highly suitable for real-time applications such as video streaming, online broadcasting, and Internet of Things (IoT) services. In broadcasting systems, edge computing enables faster content delivery and enhances overall streaming quality by minimizing latency [22].

Decentralized computing frameworks extend the concept of edge computing by distributing computational tasks across multiple interconnected nodes within a network. Instead of relying on a single centralized server, decentralized systems allow different nodes to collaboratively process and transmit data [23]. This architecture enhances system resilience, improves scalability, and reduces the risk of system failure caused by centralized infrastructure overload. In the context of broadcasting systems, decentralized edge computing frameworks can optimize media distribution, balance network traffic, and ensure consistent service performance for global audiences [24].

2.3. Digital Broadcasting and Community-Based Technology Adoption

The growth of digital media platforms has enabled communities and local organizations to participate actively in broadcasting activities through online platforms and digital communication tools. Community-based broadcasting systems allow local communities to disseminate information, share educational content, and promote local cultural activities [25]. These broadcasting initiatives often rely on accessible technologies such as internet streaming platforms, cloud storage services, and digital media production tools. As digital technology becomes more accessible, communities have greater opportunities to establish their own broadcasting networks and participate in digital communication ecosystems [26].

However, many community-based broadcasting initiatives still face technological and infrastructural limitations. Limited access to advanced computing infrastructure, insufficient technical expertise, and lack of training opportunities often hinder the effective implementation of modern broadcasting technologies. To address these challenges, capacity-building programs and community engagement initiatives are essential [9]. By introducing emerging technologies such as cloud computing and edge computing through training and collaborative programs, communities can develop the necessary skills to manage digital broadcasting systems independently. This approach not only improves broadcasting capabilities but also contributes to broader digital empowerment and technological inclusion [27].

2.4. Previous Studies

Previous studies have explored the application of cloud computing and distributed computing technologies in multimedia streaming and digital broadcasting systems [28]. Research findings indicate that integrating cloud infrastructures with edge computing technologies can significantly improve broadcasting performance, particularly in terms of latency reduction and network efficiency [29]. Several studies also highlight the importance of scalable computing architectures that can support the growing demand for multimedia streaming services and global content distribution [30].

In addition to technological advancements, recent research emphasizes the importance of digital literacy and community engagement in supporting sustainable technological adoption. Community-driven digital initiatives have been shown to enhance local innovation, improve access to information, and promote digital inclusivity [31]. However, existing research still lacks comprehensive studies that focus on the implementation of decentralized edge computing frameworks specifically for community-oriented broadcasting systems [32]. Therefore, this research seeks to address this gap by implementing a decentralized edge computing framework within a community service program to support global cloud-based broadcasting systems while simultaneously strengthening community technological capabilities [33].

Table 1. Summary of Previous Research on Cloud and Edge Computing in Broadcasting

Author	Technology	Focus	Findings
Study A	Cloud Computing	Streaming systems	Improved scalability
Study B	Edge Computing	Real-time processing	Reduced latency
Study C	Distributed Systems	Network optimization	Better resource usage
This Study	Edge + Cloud	Community broadcasting	Improved efficiency & digital empowerment

Table 1 summarizes several previous studies related to the implementation of cloud computing, edge computing, and distributed computing technologies in digital broadcasting systems. The table highlights the technological approaches adopted in prior research, the main research focus, and the key findings obtained from each study [34]. Previous studies primarily focused on improving streaming performance through scalable cloud infrastructures, optimizing network efficiency, and reducing latency in real-time multimedia applications [35].

3. RESEARCH METHODOLOGY

This study applies a structured methodological approach to implement a decentralized edge computing framework in supporting global cloud-based broadcasting systems within a community service context. The methodology is designed to ensure that technological innovation can be effectively introduced, implemented, and adopted by community participants involved in digital broadcasting activities [36]. In addition to focusing on the technical implementation of decentralized computing infrastructure, the method also emphasizes knowledge transfer and capacity building to enhance the technological competence of participants [37].

The implementation process integrates several stages, including problem identification, system design, community training, technological deployment, and evaluation. These stages aim to ensure that the decentralized edge computing framework can operate efficiently while also addressing the technological challenges faced by community-based broadcasting initiatives. By combining technical development with participatory engagement, the methodology ensures that the proposed solution is not only technically feasible but also practical and sustainable for community adoption [38].

3.1. Research Approach

This study adopts a community service approach aimed at introducing and implementing decentralized edge computing frameworks to support global cloud-based broadcasting systems [39]. The program focuses on empowering community members and digital media practitioners through knowledge transfer, technical training, and practical implementation of distributed computing technologies. By integrating technological innovation with community engagement, this initiative seeks to enhance both broadcasting system performance and the technological capabilities of participants [40].

The community service program emphasizes participatory engagement, where community members are actively involved in the learning and implementation process. Through collaborative activities such as workshops, demonstrations, and hands-on practice, participants are encouraged to understand the principles of decentralized computing and apply them in broadcasting environments. This approach ensures that technological solutions are not only theoretically introduced but also practically implemented and sustainable within community settings.

3.2. Implementation Stages

The implementation of this community service program was conducted through several structured stages to ensure effective knowledge transfer and technological adoption. These stages include needs assessment, system design, training and capacity building, system implementation, and evaluation.

The first stage involved identifying community needs related to digital broadcasting systems and technological infrastructure. This assessment aimed to understand existing challenges faced by community broadcasting initiatives, such as limited technical knowledge, inefficient broadcasting systems, and reliance on centralized cloud infrastructure. The second stage focused on designing a decentralized edge computing framework that could support broadcasting activities while remaining accessible and practical for community participants.

Table 2. Implementation Stages of the Decentralized Edge Computing Program

Stage	Activity	Main Objective	Expected Output
Needs Assessment	Identifying community broadcasting challenges and infrastructure limitations	To understand technical gaps, latency issues, bandwidth constraints, and participant needs	Community needs profile and technical problem mapping
System Design	Designing decentralized edge computing architecture integrated with cloud broadcasting platforms	To create a scalable and practical broadcasting framework	Edge-cloud system design and implementation plan
Training and Capacity Building	Conducting workshops, demonstrations, and hands-on practice	To improve participant understanding of cloud, edge, and distributed computing concepts	Increased digital literacy and technical competence
System Implementation	Deploying edge nodes and integrating them with cloud broadcasting services	To test localized processing and content distribution	Functional decentralized broadcasting prototype
Evaluation	Observing system performance and collecting participant feedback	To assess technical efficiency and community empowerment outcomes	Evaluation results on latency, bandwidth, stability,and participant competence

Table 2 summarizes the structured implementation stages of the decentralized edge computing program. Each stage was designed to ensure that the proposed framework could be introduced, practiced, implemented, and evaluated effectively. This staged approach also ensures that the community service program addresses both technical system requirements and participant capacity development.

The third stage consisted of training workshops and technical demonstrations to introduce participants to the concepts of cloud computing, edge computing, and decentralized broadcasting architectures. During this stage, participants were guided through hands-on activities such as deploying edge nodes, configuring broadcasting software, and integrating edge infrastructure with cloud-based platforms. The fourth stage involved the implementation of the decentralized framework within a simulated broadcasting environment to demonstrate real-time content distribution.

Finally, the evaluation stage was conducted to assess the effectiveness of the program in improving broadcasting performance and participant understanding of distributed computing technologies. Feedback from participants and system performance observations were used to evaluate the success of the program and identify opportunities for further improvement.

3.3. System Implementation

The decentralized edge computing framework was implemented by integrating cloud infrastructure with distributed edge nodes located near broadcasting sources. The cloud server functions as the central coordination platform for data storage and content management, while edge nodes perform localized data processing and content distribution. This architecture reduces the load on centralized cloud servers and improves content delivery performance by processing data closer to the end users.

To provide a clearer technical representation of the proposed system, Figure 2 illustrates the decentralized edge computing architecture implemented in this community service program. The architecture shows how broadcasting sources transmit media content to nearby edge nodes for localized processing, encoding, caching, and traffic filtering before being coordinated through the cloud broadcasting platform. This structure reduces the processing burden on centralized cloud servers and enables faster content delivery to global audiences.

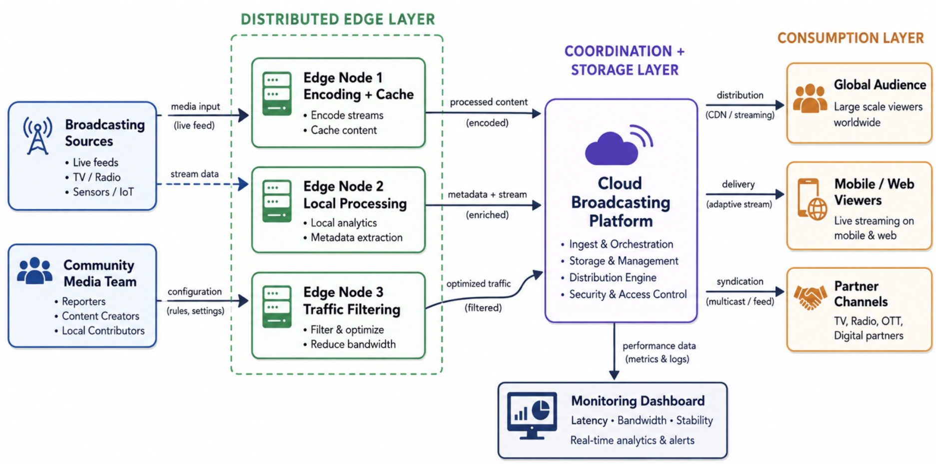

Figure 2. Decentralized Edge Computing Architecture for Cloud-Based Broadcasting

In this implementation, broadcasting content is first processed at the edge nodes before being transmitted to the cloud platform for wider distribution. This hybrid computing architecture enables efficient bandwidth utilization and reduces latency during streaming processes. Participants were trained to configure edge nodes, manage broadcasting platforms, and monitor system performance to ensure stable broadcasting operations.

3.4. Evaluation Method

The evaluation of the community service program was conducted through both qualitative and observational methods. Participant feedback was collected to assess improvements in digital literacy and technological understanding related to decentralized computing systems. In addition, system performance indicators such as latency reduction, bandwidth optimization, and broadcasting stability were observed during the implementation process.

The evaluation results were used to measure the effectiveness of the decentralized edge computing framework in supporting community-based broadcasting systems. The findings also provide insights into the potential scalability of this approach for broader digital broadcasting applications in other community environments.

4. RESULT AND DISCUSSION

The implementation of the decentralized edge computing framework within this community service program generated several important outcomes related to both technological performance and community capacity development. The framework was implemented by integrating a cloud-based broadcasting platform with several edge nodes that operate closer to broadcasting sources and end users. In this architecture, the cloud infrastructure functions as the central platform responsible for data storage, system management, and large-scale content distribution. Meanwhile, edge nodes perform localized processing tasks such as media encoding, temporary data storage, and preliminary content distribution before the data is transmitted to the cloud server. This distributed architecture enables more efficient data processing and helps reduce the dependency on centralized cloud infrastructure, which is often a limitation in traditional broadcasting systems.

Figure 3 presents the evaluation flow used to assess both technical performance and community empowerment outcomes. The evaluation begins with identifying community needs and broadcasting infrastructure limitations, followed by training, edge node deployment, cloud integration, and monitoring. The observed outcomes include reduced latency, optimized bandwidth utilization, improved streaming stability, and increased participant competence. This evaluation model highlights that the success of decentralized broadcasting infrastructure depends not only on system performance but also on community readiness and technological capacity.

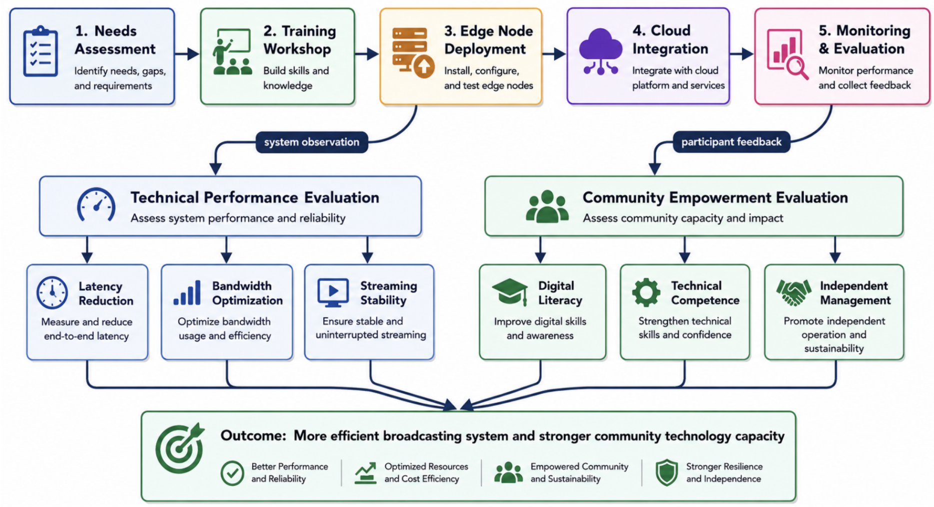

Figure 3. Evaluation Flow of Technical Performance and Community Empowerment

The implementation results indicate that the use of decentralized edge nodes can improve broadcasting efficiency and system responsiveness. By processing certain data at the network edge, the system can reduce latency during streaming activities and deliver multimedia content more effectively to users. In addition, the decentralized architecture helps optimize bandwidth utilization because some processing tasks are handled locally at the edge nodes rather than being transmitted directly to centralized servers. This approach reduces network congestion and improves the stability of broadcasting services, particularly in real-time streaming scenarios where fast data processing and reliable network performance are required.

In addition to the technical implementation, this community service program also focused on improving the technological capacity of participants involved in community-based broadcasting activities. Training sessions and workshops were conducted to introduce participants to the concepts of cloud computing, edge computing, and distributed system architectures. During these activities, participants were guided through practical exercises such as configuring broadcasting software, understanding the role of edge nodes in data processing, and learning how decentralized infrastructures can support more efficient broadcasting systems. The participatory learning approach encouraged active interaction between facilitators and participants, enabling them to gain practical knowledge and technical experience related to digital broadcasting technologies.

The results of the training activities demonstrate that participants experienced a noticeable improvement in their understanding of digital broadcasting infrastructure and distributed computing technologies. Participants showed increased confidence in operating broadcasting tools and managing digital content distribution systems. This improvement in technological competence is important for supporting sustainable community-based broadcasting initiatives, as communities are able to manage their own broadcasting platforms more independently and efficiently. Furthermore, participants also developed a better understanding of how decentralized computing can be used to address common challenges in broadcasting systems, such as latency issues and inefficient data transmission.

Overall, the findings of this study indicate that the integration of decentralized edge computing frameworks can significantly enhance the performance of global cloud-based broadcasting systems while simultaneously supporting community empowerment. From a technological perspective, the decentralized architecture improves system responsiveness, reduces latency, and optimizes network resource utilization. From a community development perspective, the program contributes to the improvement of digital literacy and technological capability among participants. These results demonstrate that combining technological innovation with community engagement can create sustainable digital solutions that support the development of modern broadcasting ecosystems.

5. MANAGERIAL IMPLICATIONS

The implementation of a decentralized edge computing framework in global cloud-based broadcasting systems provides several important managerial implications for organizations, community institutions, and digital broadcasting managers. First, the adoption of decentralized computing infrastructure encourages managers to reconsider traditional centralized broadcasting architectures that often rely heavily on distant cloud data centers. By integrating edge nodes into the broadcasting ecosystem, managers can improve system performance through faster data processing and reduced latency. This approach allows broadcasting managers to deliver content more efficiently while optimizing the use of network resources and reducing operational bottlenecks that commonly occur in centralized systems.

Second, the implementation of decentralized broadcasting infrastructures requires managerial strategies that support technological capacity building among human resources. Managers must recognize that the success of advanced digital systems is not only determined by the availability of technology but also by the ability of users and operators to manage and maintain the infrastructure effectively. Therefore, organizations and community broadcasting institutions should prioritize training programs, technical workshops, and continuous learning initiatives to improve digital literacy and technological competence among staff members and community participants.

Third, the findings of this study highlight the importance of collaborative management in the development of digital broadcasting ecosystems. The integration of decentralized edge computing frameworks requires cooperation between multiple stakeholders, including academic institutions, technology providers, broadcasting communities, and local organizations. Effective collaboration enables the sharing of knowledge, technical resources, and infrastructure development strategies that can support sustainable digital innovation. Managers should therefore encourage partnerships and cross-sector collaboration to ensure that technological initiatives can be implemented successfully and maintained over time.

Finally, from a strategic perspective, the adoption of decentralized computing frameworks can support long-term digital transformation within broadcasting organizations. By implementing scalable and flexible infrastructure, managers can adapt more easily to the rapidly evolving digital media environment and the increasing demand for high-quality streaming services. This strategic shift allows broadcasting institutions to remain competitive while also supporting broader objectives related to digital inclusion, community empowerment, and sustainable technological development.

6. CONCLUSION

The implementation of a decentralized edge computing framework in global cloud-based broadcasting systems demonstrates that distributed infrastructure can effectively improve broadcasting efficiency while supporting community-based digital empowerment. The findings show that integrating edge nodes with cloud broadcasting platforms helps reduce system dependency on centralized cloud servers, improves responsiveness, optimizes bandwidth utilization, and strengthens broadcasting stability in real-time content delivery. Through localized processing, temporary storage, and distributed content distribution, the proposed framework provides a more scalable and adaptive architecture for modern broadcasting environments, particularly for community-based digital media initiatives that face limitations in infrastructure, technical knowledge, and network capacity.

This study also confirms that technological innovation becomes more sustainable when it is combined with participatory community engagement. The training workshops and hands-on implementation activities improved participants' understanding of cloud computing, edge computing, node configuration, and decentralized broadcasting mechanisms. Participants gained practical skills in managing digital broadcasting infrastructure and became more confident in operating cloud-assisted broadcasting systems. Therefore, the contribution of this community service program is not limited to technical performance improvement, but also includes the development of community technological capacity, digital literacy, and independent broadcasting management.

Overall, decentralized edge computing provides a practical and replicable model for strengthening global cloud-based broadcasting systems while promoting inclusive digital transformation. The study supports SDG 4 through digital skills development, SDG 9 through resilient and innovative infrastructure, and SDG 17 through collaborative implementation among academic institutions, communities, and technology practitioners. Future programs may expand this framework by testing larger-scale edge node deployment, integrating artificial intelligence for automated traffic optimization, and applying quantitative performance measurement to compare latency, bandwidth usage, and streaming stability before and after implementation.

7. DECLARATIONS

7.1. About Authors

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7.2. Author Contributions

Conceptualization: DW; Methodology: NU; Software: MS; Validation: AA ; Formal Analysis: DW and NU; Investigation: MS; Resources: AA; Data Curation: DW; Writing Original Draft Preparation: MS and AA; Writing Review and Editing: AA and MS; Visualization: DW; All authors, DW, NU, MS, AA, have read and agreed to the published version of the manuscript.

7.3. Data Availability Statement

line with our commitment to research transparency, the dataset underlying this study has beenarchived in the Zenodo Repository https://zenodo.org/records/21123518 and is accessible upon request to thecorresponding author

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7.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

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