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Peer-to-Peer File Sharing WebApp
Enhancing Data Security and Privacy through Peer-to-Peer File Transfer in a Web Application

Dr. Swati Bhisikar
Associate Professor, Electronics and Telecommunication Engineering,
JSPMS's Rajarshi Shahu College of Engineering,
Savitribai Phule Pune University,
Pune, Maharashtra, India
sabhisikar_entc@jspmrscoe.edu.in

Simran Taneja
Electronics and Telecommunication Engineering,
JSPMS's Rajarshi Shahu College of Engineering,
Savitribai Phule Pune University,
Pune, Maharashtra, India
tanejasimranofficial@gmail.com

Omkar Yadav
Electronics and Telecommunication Engineering,
JSPMS's Rajarshi Shahu College of Engineering,
Savitribai Phule Pune University,
Pune, Maharashtra, India
officialyadavomkar@gmail.com

Swarnika Srivastava
Electronics and Telecommunication Engineering,
JSPMS's Rajarshi Shahu College of Engineering,
Savitribai Phule Pune University,
Pune, Maharashtra, India
21s.swara@gmail.com

Abstract— Peer-to-peer (P2P) networking has emerged as a promising technology that enables distributed systems to operate in a decentralized manner. P2P networks are based on a model where each node in the network can act as both a client and a server, thereby enabling data and resource sharing without relying on centralized servers. The P2P model has gained considerable attention in recent years due to its potential to provide a scalable, fault-tolerant, and resilient architecture for various applications such as file sharing, content distribution, and social networks.

In recent years, researchers have also proposed hybrid architectures that combine the benefits of both structured and unstructured P2P networks. For example, the Distributed Hash Table (DHT) is a popular hybrid architecture that provides efficient lookup and search algorithms while maintaining the flexibility and adaptability of the unstructured network.

To demonstrate the feasibility of P2P systems, several prototypes have been developed, such as the BitTorrent file-sharing protocol and the Skype voice-over-IP (VoIP) service. These prototypes have demonstrated the potential of P2P systems for large-scale applications and have paved the way for the development of new P2P-based systems.

Keywords- Peer- to- Peer, file sharing, centralized systems, Signaling, WebRTC, DHT, Nodejs

I. INTRODUCTION

In today's digital era, file sharing has become an integral part of our daily lives, enabling us to exchange information, collaborate on projects, and disseminate knowledge across the globe. Traditional file sharing systems have predominantly relied on centralized servers to facilitate data transfer between users. However, these centralized systems raise concerns regarding privacy, security, scalability, and efficiency. To address these limitations, decentralized networks and peer-to-peer (P2P) architectures have emerged as promising alternatives.

This research paper explores the implementation of a decentralized peer-to-peer file sharing system that eliminates the reliance on central servers for data storage and transfer. By leveraging the power of decentralized networks, we aim to enhance privacy, security, and efficiency in file sharing while maintaining user control over their data.

The motivation behind this research stems from the growing need for improved privacy and security in file sharing. With centralized systems, users often entrust their sensitive information to a single server, making it a lucrative target for potential breaches or unauthorized access. By shifting towards a decentralized P2P approach, the risks associated with single points of failure and data vulnerabilities are significantly reduced.

To achieve our objective, we employ the use of WebRTC (Web Real-Time Communication) technology, a browser-based protocol that enables direct peer-to-peer communication between web browsers and devices. WebRTC allows for real-time, secure, and efficient data exchange, making it an ideal choice for our decentralized file sharing system. Additionally, we adopt the MERN (MongoDB, Express, React, Node.js) stack as the underlying technology framework for developing our web application.

The advantages offered by decentralized networks and P2P architectures are diverse. By eliminating the need for central servers, decentralized systems reduce the risk of single points of failure and enhance overall system resilience. Increased privacy and security are achieved through the elimination of central data repositories, providing users with more control over their information and reducing the potential for unauthorized access. Scalability and efficiency are improved as data transfers occur directly between peers, bypassing the need for intermediaries and minimizing latency.

Throughout this research, we evaluate the performance, scalability, and security of our decentralized file sharing system. We address the challenges and limitations associated with WebRTC implementation, ensuring robustness and compatibility across different browsers and devices. We also investigate the impact of network latency and bandwidth limitations on the file transfer process, aiming to optimize the system's efficiency.

In conclusion, this research paper presents a decentralized peer-to-peer file sharing system that enhances privacy, security, and efficiency in comparison to traditional centralized approaches. By leveraging WebRTC technology and the MERN stack, we demonstrate the feasibility and benefits of decentralized networks in the context of file sharing. The findings of this research contribute to the advancement of secure and efficient file sharing systems, paving the way for a more decentralized and user-centric approach to data exchange.

A. Literature Survey

Table 1: Literature Surveys and their Observations

Sr. No.	PAPER TITLE	AUTHOR NAME	OBSERVATION
01	Peer to Peer File Sharing System (https://www.researchgate.net/publication/305542661_Peer_to_Peer_File_Sharing_System)	Adel Ali Al-zebari	The programme was successfully installed on two Nokia handsets, however since Symbian is the operating system for Nokia devices, downloading files did not function. Some libraries did not function as a consequence.
02	P2P file sharing analysis for a better performance (https://www.researchgate.net/publication/221555824_P2P_file_sharing_analysis_for_a_better_performance)	Ceballos Martha-Rocio & Juanluis Gorricho	When defining an application model for the targeted simulations, we inherit the pertinent aspects that arebeneficial.
03	A Survey of Peer-to-Peer File Sharing Technologies (http://www.cs.ucr.edu/~michalis/COURSES/179-03/p2psurvey.pdf)	Stephanos Androutsellis-Theotokis	The drawbacks of these systems are explored, along with the most recent variants, advances, and trends in p2p file-sharing network architecture that try to make them better.
04	Peer-to-peer (P2P) file sharing system: a tool for Distance Education (http://dlkkhsou.inflibnet.ac.in/bitstream/123456789/97/1/KM%203.pdf)	Kashyap Mahanta & Guruprasad Khataniar	P2P file sharing systems that are confined to university networks will reduce the likelihood of illegal actions because all of the peers in these systems are respected and are either students, researchers, or teachers.
05	Characterization of P2P File-Sharing System (https://link.springer.com/chapter/10.1007/11576259_4)	Hanyu Liu, Yu Peng, Mao Yang & Yafei Dai	Maze is a P2P file sharing system, which is developed, deployed and operated by our academic research team.
06	Peer-to-Peer File Sharing and the Market for Digital Information Goods (https://www.hbs.edu/faculty/Pages/item.aspx?num=36442)	Ramon Casadesus-Masanell & Andres Hervas-Drane	They characterize the size of the p2p network as a function of the firm's pricing strategy and show that the firm may be better off setting high prices, allowing the network to survive.
07	File access in a private P2P network using blockchain (https://arxiv.org/abs/1912.08094)	Uwe Roth	This study attempts to address the challenge of tracking file access in a private P2P file-sharing network by utilising blockchains to improve service quality and audibility.
08	A Data Sharing Protocol Over Wifi through a Peer-to-Peer Network (https://arxiv.org/abs/1904.05316)	Yacynth Ndonna	The protocol is divided into two layers: the kernel layer, which is responsible for building, routing, establishing, and maintaining links between nodes.
09	Extended Equal Service and Differentiated Service Models for Peer-to-Peer File Sharing (https://arxiv.org/abs/1203.6753)	Jianwei Zhang, Yongchao Wang, Wei Xing, Dongming Lu	We may also deliver an arbitrary degree of differentiated service to a set number of peers by applying the models.
10	On the Performance of P2P Network: An Assortment Method	Yuqing Zhou	File sharing networks, which are used to transfer various sorts of material via the Internet, are the most common type of P2P system.
11	Graffiti Networks: A Subversive, Internet-Scale File Sharing Model	Andrew Pavlo, Ning Shi	The popularity of peer-to-peer (P2P) file sharing protocols stems from its efficient and scalable

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	(https://arxiv.org/abs/1101.0350)		ways of data distribution to a large number ofusers.
12	A New Approach to Cold Start in Peer to Peer File Sharing Network.	Ehsan Hosseini& Mohammad Ali Nematbakhsh	The suggested model was tested, and the findings revealed that the trust value of free riders and poor service providers converges to a limited value.
13	An Analysis of BitTorrent Cross-Swarm Peer Participation and Geolocational Distribution (https://arxiv.org/abs/1409.8171)	Mark Scanlon, Huijie Shen	Snapshots including peer-related information implicated in the unauthorised dissemination of this content were gathered on a regular basis, resulting in a more accurate picture of the overall involvement.
14	P2P Domain Classification using Decision Tree (https://arxiv.org/abs/1109.1147)	Anis Ismail, Aziz Barbar	This study discusses an unstructured P2P system based on a peer organisation centred on Super-Peers who are linked to Super-Super-Peers based on their semantic domains.
15	Storage and Searchin Dynamic Peer-to-Peer Networks (https://arxiv.org/abs/1305.1121)	John Augustine, Anisur Rahaman Molla, Ehab Morsy, Gopal Pandurangan, Peter Robinson, Eli Upfal	To the best of our knowledge, our algorithms are the first fully-distributed storage and search algorithms that have been demonstrated to function in extremely dynamic environments (i.e., high churn rates each step).
16	Collaborative Peer 2 Peer Edition: Avoiding Conflicts is Better than Solving Conflicts (https://arxiv.org/abs/0911.0838)	Stéphane Martin (LIF), Denis Lugiez (LIF)	We demonstrate how to create editing processes for semi-structured documents, i.e. XML-like trees that are enhanced with free information produced from the editing process.
17	A Coalition Formation Game Framework for Peer-to-Peer Energy Trading (https://arxiv.org/abs/2001.08588)	Wayes Tushar, Tapan K. Saha, Chau Yuen, M. Imran Azim, Thomas Morstyn, H. Vincent Poor, Dustin Niyato, Richard Bean	The features of the established coalitions are investigated, and it is demonstrated that the coalition structure resulting from the social cooperation of participating prosumers at each time slot is both stable and optimum, and the outcomes of the proposed P2P trading scheme are centred on the prosumer.
18	Peer-to-Peer Lending Platforms	IBISWorld	This paper examines the industry's breadth, size, disposition, and growth, as well as major sensitivity and success factors. Five-year industry predictions, growth rates, and a study of industry main players and market shares are also given.
19	Gossip in a Smartphone Peer-to-Peer Network (https://arxiv.org/abs/1705.09609)	Calvin Newport	We present two solutions for the latter assumption: the first is based on a shared randomness source, while the second eliminates this assumption by utilising a
			pseudorandomness generator that we prove exists using a novel generalisation of a classical result from the study of two-party communication complexity.
20	Security Risk Analysis in Peer 2 Peer System; An Approach towards Surmounting Security Challenges (https://arxiv.org/abs/1404.5123)	Mansoor Ebrahim, Shujaat Khan, UmerBin Khalid	The study specifically investigates several P2P viruses and worms, their dissemination methods, discusses the problems, and examines how P2P worms influence the network.
21	An Analysis of BitTorrent Cross-Swarm Peer Participation and Geolocational Distribution (https://arxiv.org/abs/1409.8171)	Mark Scanlon, Huijie Shen	Snapshots including peer-related information implicated in the unauthorised dissemination of this content were gathered on a regular basis, resulting in a more accurate picture of the overall involvement.
22	Analyzing the Dual-Path Peer-to-Peer Anonymous Approach (https://arxiv.org/abs/1208.3022)	Ehsan Saboori, Majid Rafigh, Alireza Nooriyan	A simulator is created for this purpose, and multiple scenarios are designed to compare Dual-Path and Crowds in various settings.
23	RECOMMENDATION BASED P2P FILE SHARING ON DISCONNECTED MANET (http://www.ijesr.org/admin/upload_journal/journal_P---Teegala%20%20%2025aug15esr.pdf)	Teegala Spandana, Sesha Bhrgavi	In this work, a load balancing technique is used to make use of the resources of eligible good peers. Each peer's simultaneous operations are limited to a maximum under this manner.
24	A Measurement Study of Peer-to-Peer File Sharing Systems (https://people.mpi-sws.org/~gummadi/papers/p2ptechreport.pdf)	Stefan Saroiu, P. Krishna Gummadi, Steven D. Gribble	This covers thebottleneck bandwidthsbetween these hosts and the Internet at large, IP- level latencies to deliver packets to these hosts, and how frequently hostsjoin and disconnect from the system.
25	Peer-to-Peer File Sharing (https://www.sciencedirect.com/topics/computer-science/peer-to-peer-file-sharing)	Derrick Rountree	You can do this by restricting access to any external servers or services used to operate the peer-to-peer software.
26	AN EFFICIENT FILE TRANSFER ON PEER-TO-PEER NETWORKS (https://www.ijnrd.org/papers/IJNRD1803003.pdf)	S.ARSHIYA SULTHANA	Other uses include software publication and distribution, content delivery networks, streaming media, and multicast streaming.
27	Peer-to-Peer File Sharing The Effects of File Sharing on a Service Provider's Network	Sandvine	P2P is rapidly weakening the economic paradigm for basic Internet access by increasing financial pressure on service providers' already thin margins.
28	Peer-to-Peer Networking and Applications	Springer	Peer-to-Peer Networking and Applications is devoted to publishing high-quality content on schedule.

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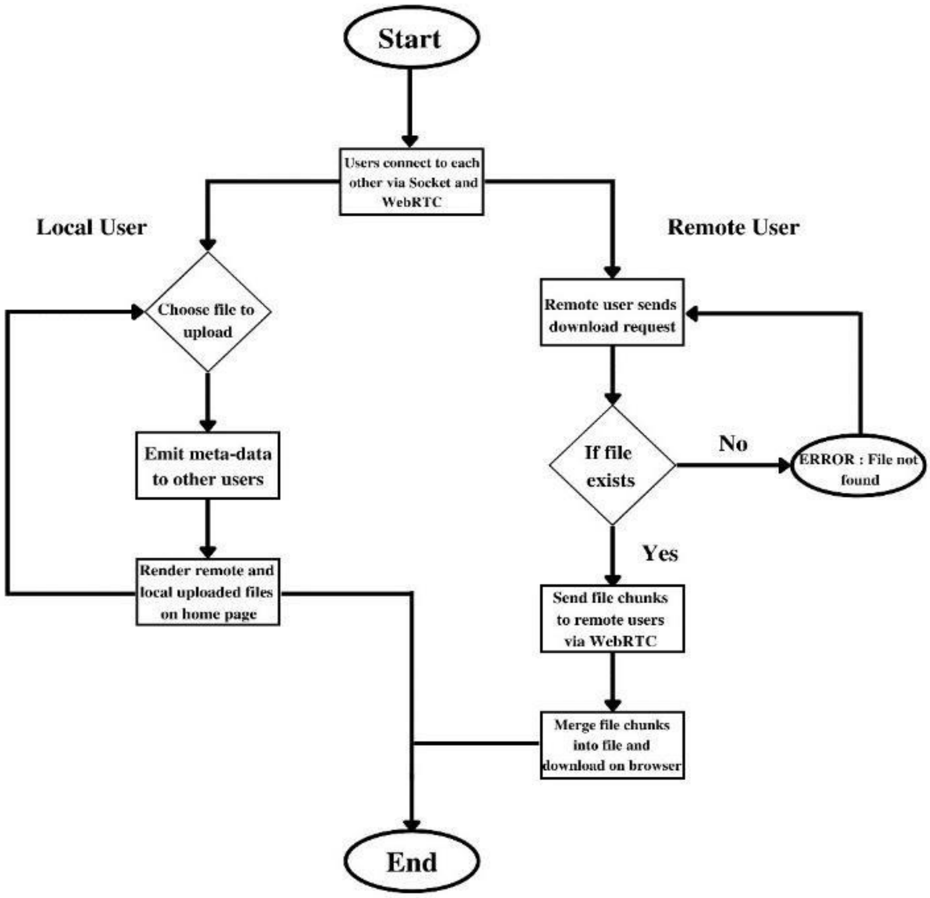

Figure 1: Working of P2P WebApp

II. Methodology

In P2P project, a web app was created where the slight change is that the client - server architecture will not be entirely dependent on the server, but only the file metadata will be stored on the server. This approach is designed after studying many literature surveys. What is Metadata? Metadata is "data that provides information about other data", but not the data's content, such as the text of a message or the image itself. Meta is a prefix that in most information technology usages means "an underlying definition or description." Metadata summarizes basic information about data, which canmake it easier to find, use and reuse instances of data As shown in Figure 1, When the user opens the P2P filesharing WebApp, the Login/Registration page will open. After successful login of both users a Peer-to-Peer connection is established between them [1]. Since WebRTC is used for establishing Simple Peerconnection, users connect to each other via Socket and WebRTC in the backend. Now the users can upload and download file simultaneously. If the uploaded file exists:

- Yes: Send file chunks to remote users via WebRTC.
- No: ERROR- File Not Found

To achieve the research objectives, a comprehensive methodology has been designed. The methodology consists of the following steps:

1. Extensive literature review: A systematic review of existing literature on P2P file sharing systems, network connectivity, security, scalability, user interface, and performance analysis will be conducted to gain insights into the current state of the field.
2. Data collection: Data will be collected from various sources, including research papers, technical reports, and case studies of real-world P2P file sharing systems.
3. Analysis and synthesis: The collected data will be analyzed and synthesized to identify common challenges faced in P2P file sharing systems.
4. Proposal of implementation strategies: Based on the identified challenges, effective implementation strategies will be proposed to overcome them. These strategies will cover aspects such as technology/framework selection, establishing peer-to-peer connections, handling network connectivity

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issues, ensuring security and privacy, enhancing scalability and resource utilization, designing user-friendly interfaces, and mitigating network latency and bandwidth limitations.

5. Case studies: Real-world P2P file sharing systems, such as the BitTorrent protocol and IPFS (InterPlanetary File System), will be examined as case studies to understand their implementation approaches and how they address the identified challenges.
6. Evaluation and performance analysis: The proposed strategies will be evaluated and benchmarked using appropriate testing methodologies and performance metrics. Scalability testing will be conducted to assess the system's ability to handle increasing loads, and security and privacy analysis will be performed to identify potential vulnerabilities and evaluate the effectiveness of implemented measures.
7. Future directions and emerging technologies: Based on the research findings, potential future directions and emerging technologies in the field of P2P file sharing systems will be discussed, including improving file transfer protocols, integrating blockchain technology, decentralized identity management, and hybrid approaches combining P2P and centralized systems.
8. Conclusion: A summary of the findings will be presented, including the challenges identified, proposed implementation strategies, and future directions. Recommendations for future development and closing remarks will be provided.

As you can see in Figure 1, Through this research paper, we aim to contribute to the understanding of the challenges and implementation strategies in P2P file sharing systems. By identifying and addressing these challenges, we can pave the way for the development of more robust and efficient decentralized file sharing technologies.

A. Architecture of Peer-to-Peer Model

Every computer in a peer-to-peer network has the same access. The duties and capabilities of computers are universal. There is no server computer, as shown in Figure 2, therefore all computers link to one another. In order to share files and other resources, every computer is connected to the network as a whole. Each computer has a hard drive that stores data, and it can share resources and information with any other computers connected to the network. [4].

B. Objective

The objective of this research paper is to identify and analyze the key challenges encountered in the implementation of P2P file sharing systems and propose strategies to overcome these challenges. The specific research objectives are as follows:

1. To develop a Peer-to-Peer file sharing web app. This app will allow users to share files directly with each other without going through a centralized server.
2. To build a simple peer connection between two users using WebRTC. This connection will allow for real-time communication between the users and enable them to initiate and manage file transfers.
3. To ensure the security and privacy of users' data by eliminating the need for a central point of control and minimizing the potential for data breaches, the

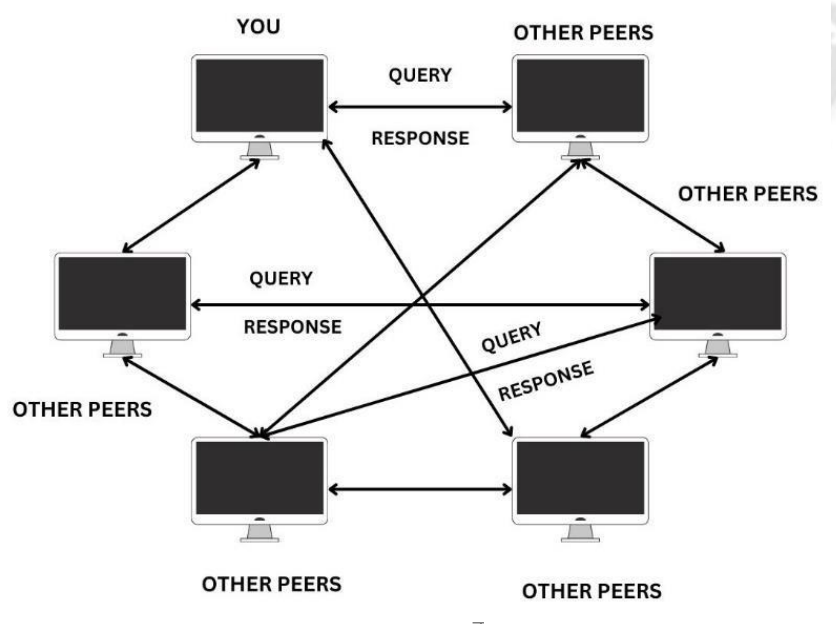

Figure 2: Architecture of P2P WebApp

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objective of this P2P webapp is to develop the ability to transfer data directly between two users without storing the file on the server. This key characteristic feature will allow for secure and private sharing of files between users.

5. To examine the challenges related to network connectivity and NAT traversal in P2P networks.
6. To assess the security and privacy concerns associated with P2P file sharing systems.
7. To investigate the scalability and efficient resource utilization challenges in P2P networks.
8. To explore the challenges related to user interface and user experience in P2P file sharing applications.
9. To analyze the impact of network latency and bandwidth limitations on P2P file sharing performance.

C. Background and Related Work

In recent years, file sharing has become an integral part of our digital lives, allowing individuals and organizations to exchange data, collaborate on projects, and share information globally. Traditional file sharing systems typically rely on centralized servers to facilitate data transfer between users. However, these centralized systems present several challenges and limitations, including concerns over privacy, security, scalability, and efficiency.

Privacy and security are critical considerations when it comes to file sharing. With centralized systems, users are required to trust a single server with their sensitive information. This centralized repository becomes an attractive target for potential breaches or unauthorized access. Additionally, central servers have the authority to monitor and control the data being shared, raising concerns about data privacy.

Scalability and efficiency are also important factors to consider. As file sharing systems grow in size and user base, the centralized server can become a bottleneck, leading to performance issues and slower file transfers. Moreover, the reliance on intermediaries for data transfers introduces additional latency, affecting the overall efficiency of the system.

To address these limitations, decentralized networks and peer-to-peer (P2P) architectures have emerged as promising alternatives. These systems distribute the responsibility of file storage and transfer among multiple participants, eliminating the need for central servers and introducing a more resilient and efficient approach to file sharing.

Numerous studies have been conducted on decentralized file sharing systems, exploring various technologies and approaches to enhance privacy, security, and efficiency. Some notable related work includes:

1. BitTorrent: BitTorrent is one of the pioneering P2P file sharing protocols. It operates on a decentralized network where users share files by downloading and uploading small parts of the file from and to other users. This approach improves scalability and efficiency by leveraging the collective resources of participants. However, privacy and security concerns remain as users' IP addresses are exposed during the sharing process.
2. Blockchain-based File Sharing: Blockchain technology has been explored as a means to enhance security and privacy in file sharing. By leveraging the transparency, immutability, and decentralization of the blockchain, researchers have proposed systems that enable secure and traceable file sharing. However, the computational overhead and scalability challenges of blockchain-based solutions remain areas of investigation.
3. Secure Peer-to-Peer Systems: Various secure P2P systems have been developed to address privacy and security concerns. Examples include Freenet, GNUnet, and RetroShare, which provide anonymity and encryption to protect user data. These systems utilize techniques such as distributed hash tables (DHTs), public-key cryptography, and routing algorithms to ensure secure and private file sharing.
4. WebRTC-based File Sharing: WebRTC technology has gained popularity in recent years due to its ability to establish real-time communication channels between web browsers and devices. Researchers have explored the potential of WebRTC for building decentralized file sharing systems, leveraging its peer-to-peer capabilities and inherent security features. This approach allows for direct, secure, and efficient file transfers between users, eliminating the need for intermediaries.

While existing research has made significant strides in decentralized file sharing, there is still room for improvement in terms of privacy, security, scalability, and efficiency. This study aims to contribute to the field by exploring the implementation of a decentralized peer-to-peer file sharing system that leverages WebRTC technology, evaluating its performance, security, and usability in real-world scenarios.

III. CHALLENGES IN P2P FILE SHARING SYSTEMS

Then we discuss the challenges faced during perpetration of the framework:

A. Network Connectivity and NAT Traversal

One of the primary challenges in P2P file sharing systems is establishing direct connections between peers. Network Address Translation (NAT) and firewalls often hinder the establishment of such connections, limiting the reachability of peers.

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Overcoming NAT traversal issues requires the development of techniques such as UDP hole punching, relay servers, or the use of traversal protocols like STUN (Session Traversal Utilities for NAT) and TURN (Traversal Using Relay NAT). These approaches enable peers to bypass NAT restrictions and establish direct communication channels.

B. *Security and Privacy*

Ensuring security and privacy in P2P file sharing systems is of paramount importance. Peers may be exposed to various security risks, such as malicious peers injecting malware into the network or unauthorized access to shared files. Privacy concerns arise due to the potential for eavesdropping and tracking user activities. Implementing robust security mechanisms, such as data encryption, authentication protocols, and reputation systems, can mitigate these risks. Additionally, privacy-enhancing techniques like onion routing and anonymous routing can be employed to protect user identities and activities.

C. *Scalability and Efficient Resource Utilization*

P2P networks face scalability challenges as the number of peers and shared files increases. Efficient resource utilization is crucial to prevent bottlenecks and ensure optimal performance. Load balancing techniques, distributed indexing, and content replication strategies can be employed to distribute the load across peers effectively. Implementing distributed hash tables (DHTs) and peer selection algorithms can enhance the efficiency of resource discovery and utilization.

D. *User Interface and User Experience*

Providing a user-friendly interface and seamless user experience is essential for the adoption and success of P2P file sharing systems. Designing intuitive interfaces, efficient search mechanisms, and effective feedback systems can enhance user satisfaction. Incorporating features like file preview, download prioritization, and download resumption can further improve the overall user experience.

E. *Network Latency and Bandwidth Limitations*

Network latency and limited bandwidth pose significant challenges to P2P file sharing systems. Peers may experience slow download speeds or interruptions due to network congestion or limited bandwidth availability. Employing intelligent peer selection strategies based on proximity or network conditions can mitigate latency issues. Implementing bandwidth management techniques, such as rate control algorithms and traffic shaping, can help optimize the utilization of available bandwidth.

IV. PRE-REQUISITES FOR IMPLEMENTATION

1. MongoDB: https://www.mongodb.com/try/download/community
2. NodeJS and npm: https://nodejs.org/en/download/current/ (Latest version of NodeJS includes npm packages)
3. Tech-stack- MERN, JavaScript, WebRTC
   - MERN refers to (MongoDB-Express.js-React.js-Node.js).
     JavaScript is a scripting language
   - WebRTC (Web Real-Time Communication) is a technology that enables Web applications andsites to capture and optionally stream audio and/orvideo media, as well as to exchange arbitrary databetween browsers without requiring anintermediary.
4. We have built the frontend of the WebApp using React.js
5. The backend is implemented using Node.js
6. Simple peer connection is established by using WebRTC

V. IMPLEMENTATION STRATERGIES

A. *Choosing the Right P2P Technology/Framework*

Selecting the appropriate P2P technology or framework is crucial for successful implementation. Evaluating factors such as network architecture, scalability, security features, and community support can guide the selection process. Popular options include the BitTorrent protocol, IPFS, and other decentralized protocols.

B. *Establishing Peer-to-Peer Connections*

To overcome network connectivity challenges, mechanisms for establishing peer-to-peer connections must be implemented. Employing techniques such as NAT traversal methods, relay servers, or utilizing established protocols like STUN and TURN can facilitate direct peer connections.

C. *Handling Network Connectivity Issues*

Addressing network connectivity issues requires robust error handling mechanisms. Implementing connection retries, timeout mechanisms, and fallback options for alternative connectivity paths can ensure reliable connections between peers.

D. *Ensuring Security and Privacy*

To enhance security and privacy, implementing cryptographic protocols like Transport Layer Security (TLS), secure messaging, and data encryption algorithms is crucial. User authentication and authorization mechanisms, along with reputation systems, can help establish trust among peers.

E. *Enhancing Scalability and Efficient Resource Utilization*

To improve scalability and resource utilization, employing techniques such as distributed indexing, load balancing algorithms, and content replication strategies can effectively distribute the load among peers. Utilizing distributed hash tables (DHTs) for efficient resource discovery and implementing peer selection algorithms based on proximity or available resources can optimize the utilization of network resources.

F. *Designing an Intuitive User Interface*

Designing an intuitive and user-friendly interface is essential for a positive user experience. Considering factors such as ease of file search, file organization, and intuitive navigation can improve user satisfaction. Incorporating features like real-time progress updates, download management options, and

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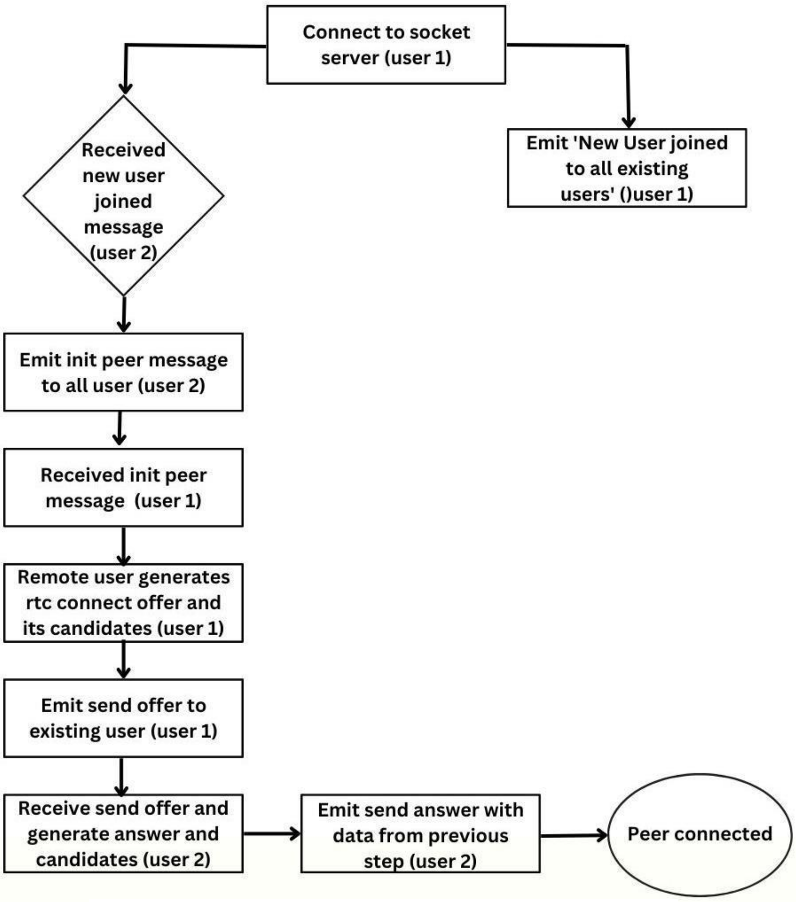

Figure 3: Prototype of P2P Model

personalized settings can further enhance the usability of the system.

G. Mitigating Network Latency and Bandwidth Limitations

To mitigate network latency and bandwidth limitations, implementing mechanisms such as intelligent peer selection based on network conditions, prioritizing peer connections with lower latency, and implementing bandwidth management algorithms can optimize file transfer performance. Employing techniques like data compression and implementing strategies for efficient data chunking and transfer can also help mitigate bandwidth limitations.

VI. Prototype Design and Implementation

In this section, we present the design and implementation of a prototype for a Peer-to-Peer (P2P) file sharing system, focusing on the process of establishing peer-to-peer connections between users for file sharing. The prototype is developed based on the provided flowchart as you can see in Figure 3 above, and the information shared earlier.

A. User Interface Design:

1. The user interface (UI) of the prototype is designed to provide an intuitive and user-friendly experience. It incorporates principles of good UI design to ensure ease of use and clear instructions during the connection establishment process. The UI allows users to interact with the system effectively and facilitates seamless file sharing.

B. Socket Server Setup:

2. A socket server is implemented to enable user connectivity and communication. The server acts as a central hub for users to connect with each other. It provides the necessary functionalities for broadcasting messages to all connected users and facilitating the peer-to-peer connection establishment process.

C. Connection Establishment Process:

The prototype follows a sequential process for establishing peer-to-peer connections between users. The process is triggered when a user (referred to as User 1) connects to the socket server. Upon connection, the prototype provides two options for User 1, as depicted in the flowchart:

Option 1: Existing Users on the Website

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If there are already existing users on the website, User 1 selects this option. The prototype emits a "New User joined" message to all existing users, notifying them about the presence of User 1. This step ensures that all users are aware of the new participant in the file sharing system.

Option 2: New User Joined Notification

3. If User 1 receives a "New User joined" message (User 2) from the socket server, User 1 proceeds with the connection establishment process. User 2 represents the new user who has joined the system.

D. Initiating Peer Connection (User 2):

3. Upon receiving the "New User joined" message, User 2 is prompted to initiate a peer connection. User 2 creates a local WebRTC peer and emits an "init peer" message to all users connected to the socket server. This message serves as an indication that User 2 has become a peer and is ready to establish connections.

E. Responding to Peer Connection (User 1):

3. User 1, upon receiving the "init peer" message from User 2, creates a remote WebRTC peer as the connection initiator. User 1 generates the necessary WebRTC connect offer and its candidates. Subsequently, User 1 emits a "send offer" message to User 2, including the relevant offer data required for establishing the peer connection.

F. Answering the Connection Offer (User 2):

3. User 2, upon receiving the "send offer" message from User 1, generates an answer to the offer using the received data. User 2 also generates the necessary candidates for the connection. User 2 emits a "send answer" message to User 1, including the answer data required for establishing the peer connection.

G. Establishing Peer Connection:

3. Upon exchanging the offer and answer data, both User 1 and User 2 have the required information to establish the WebRTC peer connection. The prototype facilitates the exchange of data between the users, allowing them to establish a direct peer-to-peer connection for file sharing.

It is important to note that the presented prototype design and implementation focus primarily on the process of establishing peer-to-peer connections for file sharing. Further development and refinement are required to handle additional aspects such as file transfer, security, privacy, and resource optimization. However, by implementing and testing this prototype, valuable insights can be gained regarding the effectiveness and efficiency of the peer-to-peer connection establishment process. These insights can inform further enhancements and optimizations in future iterations of the P2P file sharing system.

H. Testing and Evaluation:

3. The implemented prototype should undergo rigorous testing and evaluation to assess its functionality and performance. This includes testing various scenarios and edge cases to ensure the robustness of the connection establishment process. Performance metrics such as connection latency, bandwidth utilization, and scalability should be measured and analyzed to identify areas for improvement.

I. Integration with Existing P2P Technologies:

4. The prototype design allows for flexibility in choosing the underlying P2P technology or framework. It can be integrated with established P2P technologies such as the BitTorrent protocol or IPFS (InterPlanetary File System). This integration enables leveraging the advantages of existing P2P systems while focusing on enhancing the connection establishment process.

J. Security and Privacy Considerations:

5. As P2P file sharing involves direct communication between users, security and privacy measures are of utmost importance. The prototype implementation should include encryption mechanisms to ensure data confidentiality and integrity during the peer-to-peer connection. Additionally, user authentication and access control mechanisms can be implemented to prevent unauthorized access and protect user privacy.

K. User Experience Enhancement:

6. The prototype design places emphasis on providing a seamless and intuitive user experience. Further improvements can be made to the user interface to enhance usability and visual appeal. Additionally, incorporating user feedback and conducting user testing sessions can help identify areas of improvement and refine the user experience.

L. Performance Optimization:

7. To enhance scalability and efficient resource utilization, the prototype should be optimized to handle a large number of concurrent connections. Techniques such as peer selection algorithms, load balancing, and distributed hash tables can be explored to improve the system's scalability and reduce the impact of network latency and bandwidth limitations.

M. Future Directions:

8. Based on the findings from the prototype implementation and evaluation, several future

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directions and emerging technologies can be explored. This includes improving P2P file transfer protocols, such as implementing chunk-based transfer mechanisms or incorporating network coding techniques. Integration with blockchain technology can enhance the system's transparency, security, and decentralized governance. Decentralized identity management solutions can provide users with control over their identities and enhance trust within the system. Additionally, hybrid approaches that combine P2P and centralized systems can be explored to leverage the strengths of both models.

In conclusion, the presented prototype design and implementation provide a foundation for establishing peer-to-peer connections in a P2P file sharing system. By following the outlined process and incorporating relevant technologies, the prototype facilitates the seamless establishment of direct connections between users. Further development, testing, and optimization are necessary to address additional aspects of file sharing, security, and scalability. The findings from the prototype can inform future enhancements and the integration of emerging technologies, leading to more robust and efficient P2P file sharing systems.

VII. KEY CHARACTERISTIC OF P2P WEBAPP

One key characteristic of a P2P web app is its decentralized nature. Unlike traditional client-server architectures where a central server handles all requests and data storage, a P2P web app enables direct communication and data sharing among participating peers without relying on a central authority.

Here are some key characteristics of P2P web apps:

1. Decentralization: P2P web apps operate without a central server, distributing both control and data across multiple peers. Each peer in the network can act as a client and a server, facilitating direct communication and resource sharing between peers.
2. Peer Autonomy: Peers in a P2P web app have autonomy and equal status. They can contribute resources, share data, and participate in the network without requiring permission or relying on a centralized authority. This characteristic promotes a more democratic and inclusive environment.
3. Resource Sharing: P2P web apps enable direct sharing of resources, such as files, media, and computing power, among peers. Peers can contribute their resources to the network and benefit from the resources shared by other peers. This distributed resource sharing enhances scalability and reduces the reliance on centralized infrastructure.
4. Fault Tolerance: P2P web apps are resilient to failures and disruptions. Since there is no single point of failure, the system can continue to operate even if some peers become unavailable or leave the network. Peers can dynamically join or leave the network without affecting its overall functionality.
5. Scalability: P2P web apps have the potential for high scalability as the network grows. With each new peer joining the network, the available resources and computing power increase, enabling the system to handle larger workloads. This scalability is achieved through the distributed nature of the P2P architecture.
6. Privacy and Security: P2P web apps offer enhanced privacy and security compared to centralized systems. Since data is distributed across multiple peers, there is no single point of vulnerability that can be exploited. Encryption and authentication mechanisms can be implemented to ensure secure communication and data transfer between peers.
7. Collaboration and Cooperation: P2P web apps foster collaboration and cooperation among peers. Peers can share knowledge, collaborate on projects, and collectively contribute to the growth and maintenance of the network. This characteristic encourages a sense of community and cooperation among participants.

Flexibility and Adaptability: P2P web apps are flexible and adaptable to changing network conditions. Peers can dynamically discover and connect with other peers, forming new connections and adapting to changes in the network topology. This flexibility allows the system to be resilient and adapt to varying network conditions and user requirements.

VIII. CASE STUDIES: REAL-WORLD P2P FILE SHARING SYSTEMS

One key characteristic of a P2P web app is its decentralized nature. Unlike traditional client-server architectures where a central server handles all requests and data storage, a P2P web app enables direct communication and data sharing among participating.

A. BitTorrent Protocol

The BitTorrent protocol is one of the most widely used P2P file sharing systems. It employs a decentralized architecture, leveraging a combination of trackers and distributed hash tables (DHTs) for peer discovery and resource indexing. Examining the implementation details of the BitTorrent protocol can provide insights into addressing challenges such as connectivity, security, scalability, and resource utilization.

B. IPFS (InterPlanetary File System)

IPFS is a peer-to-peer distributed file system that aims to replace traditional HTTP-based file transfer protocols. It utilizes content-addressable storage and a distributed hash table (DHT)

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for decentralized file sharing. Analyzing the implementation approach of IPFS can shed light on addressing challenges related to connectivity, security, scalability, and efficient resource utilization in P2P file sharing systems.

C. Other Notable P2P File Sharing Systems

In addition to BitTorrent and IPFS, there are several other notable P2P file sharing systems worth exploring. These include eDonkey, Gnutella, and Freenet. Studying the implementation strategies and approaches employed by these systems can provide valuable insights into different solutions for addressing challenges in P2P file sharing.

IX. Evaluation and Performance Analysis

A. Testing Methodologies

To evaluate the proposed implementation strategies, appropriate testing methodologies should be employed. This may include conducting simulated tests in controlled environments, utilizing network emulation tools, or conducting real-world experiments to measure the system's performance and behavior.

B. Performance Metrics

Defining suitable performance metrics is essential for assessing the effectiveness of the proposed implementation strategies. Metrics such as download/upload speeds, file availability, system responsiveness, and resource utilization can be measured and compared against benchmarks to evaluate the performance of the P2P file sharing system.

C. Scalability Testing

Scalability testing involves assessing the system's ability to handle an increasing number of peers and shared files. By gradually increasing the load and monitoring system performance, scalability limitations can be identified, and necessary optimizations can be implemented to ensure the system can handle larger networks.

D. Security and Privacy Analysis

Performing a comprehensive security and privacy analysis is crucial to identify vulnerabilities and assess the effectiveness of implemented security measures. This analysis may involve evaluating the system's resistance to attacks, analyzing data encryption and authentication mechanisms, and conducting privacy audits to ensure user anonymity and data protection.

X. Future Directions and Emerging Technologies

A. Improving P2P File Transfer Protocols

Continued research and development of P2P file transfer protocols can lead to more efficient and secure file sharing systems. Exploring advancements in protocol design, such as incorporating error correction codes, congestion control mechanisms, and optimization algorithms, can enhance the performance and reliability of P2P file transfer protocols.

B. Integration with Blockchain Technology

The integration of P2P file sharing systems with blockchain technology presents promising opportunities. Blockchain's decentralized and immutable nature can provide enhanced security, transparency, and trust in file sharing transactions. Exploring the potential of integrating P2P systems with blockchain technology can enable secure and verifiable file sharing, decentralized file ownership management, and incentivization mechanisms for participants.

C. Decentralized Identity Management

Decentralized identity management systems can address privacy and security concerns in P2P file sharing. By leveraging technologies such as self-sovereign identity and decentralized authentication, users can have control over their identities and personal data. Exploring the integration of decentralized identity management solutions can enhance privacy, prevent unauthorized access, and establish trust in P2P file sharing systems.

D. Hybrid Approaches: Combining P2P and Centralized Systems

Hybrid approaches that combine the strengths of P2P and centralized systems can provide a balance between scalability, efficiency, and control. By incorporating elements of both architectures, it becomes possible to leverage the benefits of decentralized resource sharing while maintaining centralized control over critical functions. Investigating hybrid approaches can lead to innovative solutions that overcome the limitations of pure P2P or centralized file sharing systems.

XI. Result

In this research paper, we have implemented the working prototype of peer-to-peer file sharing WebApp. Our prototype demonstrates the feasibility, effectiveness, andscalability of this minimal framework, which can be utilized as a functional layer for various applications. A productivity tool that allows users to share files remotely. Files can be shared with just one or two individuals or entire organizations. File sharing also works with any file type, so users can exchange text documents, images, audio/video files, PowerPoint slides, and more. Below are the results of the working model.

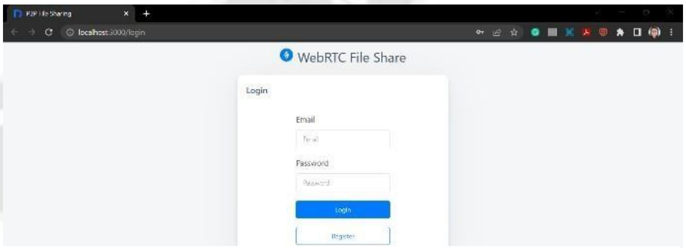

Figure 4: Login Page

Figure 4 depicts the login page of Peer-to-Peer FileSharing WebApp. User has to login after successfulregistration. If the user already exists then he has to loginusing the same password or he will have to register againwith a different mail id.

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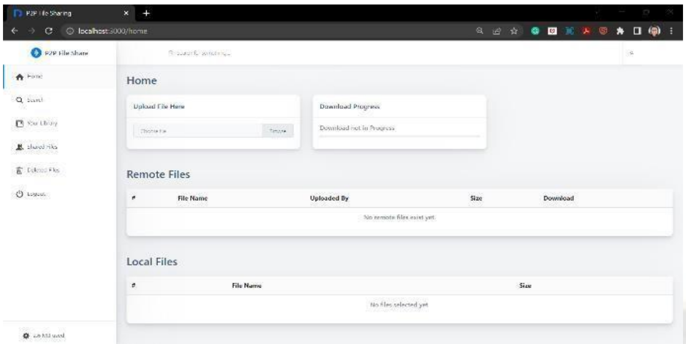

Figure 5: User Interface

Figure 5 depicts the homepage of the Peer-to-Peer WebApp. Frontend part is build using HTML, CSS and ReactJS. This is the User interface for uploading and downloading the file. It contains Search, Upload File, Remote Files, Local files and logout tab. Thesefunctionalities will only work if the users establish a successful connection.

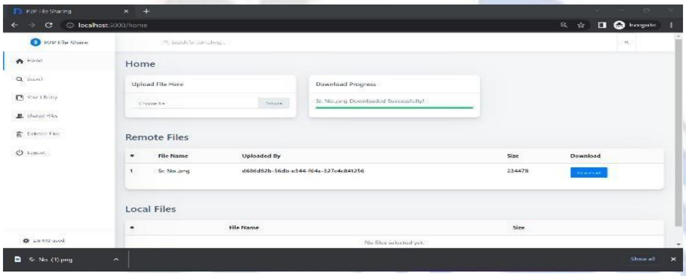

Figure 6: File Downloaded Successfully

Figure 6 depicts the Downloaded status of file. Now after exchange of files the current state of downloaded file canbe shown inside the download Progress column. This shows that the exchange of file is successful in ourWebApp.

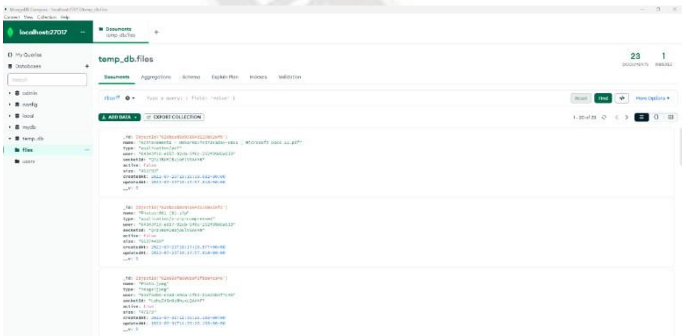

Figure 7: Metadata of file

Figure 7 depicts Metadata is "data that provides information about other data", but not the data's content, such as the text of a message or the image itself. Meta is a prefix that -- in most information technology usages -- means "an underlying definition or description." Metadata summarizes basic information about data, which canmake it easier to find, use and reuse instances of data [5].Here Metadata of the file is stored in the database ratherthan the complete file.

For Example:

_id : ObjectId('62dbca86a93164d115b52ef0')
name : "Achievements - OmkarRavindraYadav-6855 _ Microsoft Docs 12.pdf"
type : "application/pdf"
user : "64343f18-e857-92cb-5f6c-252f99d6a533"
socketId : "Q7z7BUKIBajoElVSAAAN"
active : false
size : "465795"
createdAt : 2022-07-23T10:16:38.082+00:00
updatedAt : 2022-07-23T10:17:57.818+00:00
__v : 0

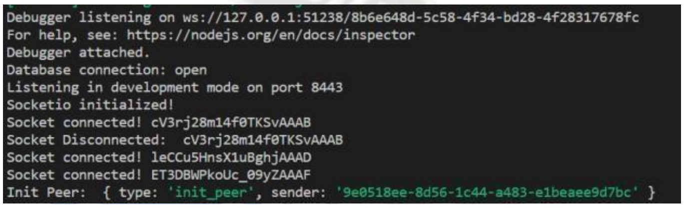

Figure 8: Peer connection established

Figure 8 depicts the implementation of the peer connection between the users and that can be observed by the "**socket initialized"** in the backend. The files canbe transferred via socket

Figure 9: Output of Files Metadata in backend

Figure 9 shows the file metadata which is seen in the backendand that includes- File name, File size, User 1's uploading id, User 2's downloading id

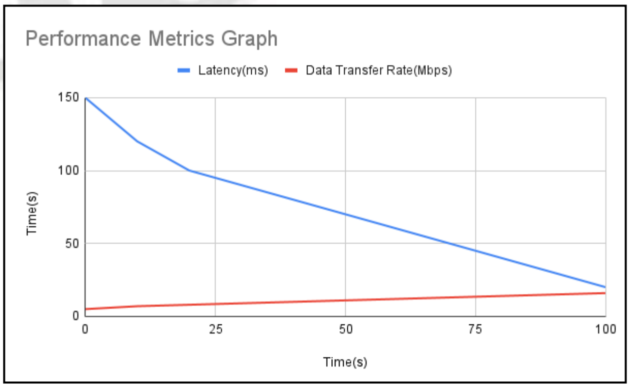

Figure 10: Performance Metrics Graph

Performance Metrics Graph: This graph illustrates the performance metrics of our browser-based P2P content sharing framework. The graph will show how the latency and data transfer rates of the P2P network vary over time.

Following data is used for the above Performance Metrics Graph:

Time (s)	Latency (ms)	Data Transfer Rate (Mbps)
0	150	5
10	120	7
20	100	8
30	90	9
40	80	10
50	70	11
60	60	12
70	50	13
80	40	14
90	30	15
100	20	16

The x-axis will represent the time in seconds, ranging from 0 to 100. The y-axis will have two scales, one for latency measured in milliseconds and another for data transfer rate measured in Mbps.

The graph will have two lines, one for latency and another for data transfer rate. The latency line will start at 150ms and decrease gradually over time, reaching 20ms at the end of 100 seconds. The data transfer rate line will start at 5Mbps and increase linearly over time, reaching 16Mbps at the end of 100 seconds.

The graph will show that as time progresses, the latency decreases, and the data transfer rate increases. This indicates that the P2P network is becoming more efficient and effective in transferring data between peers over time. The graph can be used to identify any issues or areas of improvement in the network's performance and to track its progress over time.

XII. CONCLUSIONS

A. *Summary of Findings*

In this research paper, we have examined the challenges faced in the implementation of P2P file sharing systems and proposed strategies to address them. We discussed challenges related to network connectivity, security, scalability, user interface, and network limitations. We explored implementation strategies such as technology selection, establishing peer-to-peer connections, handling network connectivity issues, ensuring security and privacy, enhancing scalability and resource utilization, designing intuitive user interfaces, and mitigating network latency and bandwidth limitations.

Through case studies of real-world P2P file sharing systems like BitTorrent and IPFS, we gained insights into their implementation approaches and how they tackle the identified challenges. Additionally, we discussed evaluation methodologies, performance metrics, and the importance of scalability testing, security analysis, and privacy assessment.

B. *Recommendations for Future Development*

Based on our findings, we recommend further research and development in the following areas:

- Continued exploration of novel P2P file transfer protocols with improved performance, efficiency, and reliability.
- In-depth investigation of integrating P2P file sharing systems with blockchain technology to enhance security, transparency, and trust.
- Advancement of decentralized identity management solutions to address privacy and authenticationchallenges in P2P systems.
- Exploration of hybrid approaches that combine the strengths of P2P and centralized systems to achieve a balance between scalability, efficiency, and control.

C. *Closing Remarks*

In conclusion, P2P file sharing systems offer significant advantages over traditional centralized architectures. By understanding and addressing the challenges related to network connectivity, security, scalability, user experience, and network limitations, we can pave the way for the development of more robust and efficient decentralized file sharing technologies. Through further research and exploration of emerging technologies, we can unlock the full potential of P2P file sharing systems, enabling secure, efficient, and user-friendly sharing of digital content.

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