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A coin-based incentive model for curbing free riding in peer-to-peer networks

[1]Oluwafolake E. Ojo, [2]Ibrahim K. Ogundoyin, [3]Michael O. Abolarinwa, [4]Ayodeji J. Bamidele

[1]Department of Information Technology, Osun State University, Osogbo, Nigeria, oluwafolakeojo5@gmail.com
[2]Department of Computer Science, Osun State University, Osogbo, Nigeria, ibraheem.ogundoyin@uniosun.edu.ng
[3]Department of Cyber Security, Osun State University, Osogbo, Nigeria, gbenga1abolarinwa@gmail.com
[4]Department of Computer Science, Federal University of Agriculture, Abeokuta, Nigeria, bamideledeji001@gmail.com

Abstract

Peer-to-peer networks have emerged and evolved in their use due to the limitations of the centralised client-server network architecture. They are used in applications such as video games for text, images, sound, and video. Resource sharing in peer-to-peer networks has enhanced multimedia distribution, system scalability, and performance. Peer-to-peer systems depend on the unimpeded collaboration of peers on the network, leading to certain peers declining to provide resources to the network and being identified as free riders. Free riding has become a significant concern in peer-to-peer systems and requires attention. Free-riding activities impact the performance of a peer-to-peer video-on-demand system, reducing its efficiency. This study explores the utilisation of incentive mechanisms to address free-riding on peer-to-peer networks and suggests an effective overlay network for this purpose. The coin-based approach, an incentive mechanism, aims to mitigate free riding by rewarding participating peers with coins and distinguishing those who do not participate

Keywords: Coin-based model, Peer-to-peer network, free riding, Network security

I. Introduction:

Peer-to-Peer (P2P) is a type of distributed computing, which avoids the use of central servers. In this approach, users share computer resources directly among themselves (Androutsellis-Theotokis and Spinelli, 2004). In a Peer-to-peer system (P2P), users exchange resources like processing power, content, space, and channel capacity

With other network users directly, removing the need for cooperative mechanisms like servers, or stable hosts. In case of P2P model, each node is deemed similarly important and nodes works together in order to complete the same purpose (Sable et al., 2022). Centralized network generally have the vulnerabilities that malicious operators take of use as a single point of failure. Networks that are decentralized do better when more members take part in

the operation of the network. Like most decentralized networks, peers are encouraged to participate and cooperate by incentive systems which also the main factors are ensuring the network's functionality and security (Ihle et. al., 2023). The recent research has indicated that P2P networks are more preferred for block-chain infrastructures mostly due to their flexibility and decentralized setup (Tang et al., 2023; Howell et al., 2023). Another thing is that computer networking specialists from academia and business are rapidly switching to P2P networks. In order to offer high resolution live streaming and video-on-demand to users, researchers have recently been investigating the deployment of peer-to-peer networks (Turukmane et al., 2024). After the pandemic, video conferencing and other video streaming forms replace traditional technologies in virtual communications. The P2P distribution system (Wei & Bojja Venkatakrishnan, 2023) effectively distributes videos, utilizing the link bandwidth and avoiding multiple copies of video transfers (Ozcinar et al., 2019). Although P2P networks are recently widely applied, they still face challenges such as free riding habits,
White washing, limited search-scalability, spreading of false and harmful content, and absence of strong trust framework (Singh et al., 2019).

Due to this issue of free-riding, the speed and efficiency of current P2P systems are worsening (Zhang et al. 2023). Consistent resource sharing between nodes is among the most important requirements for a P2P-based network to run smoothly. The phenomenon of free-riding severely hinders the fundamental idea of P2P networks. Peers are widely renowned for relentless take of other peers' resources. Performance loss can occur as a result of such behavior (Kurdi et al., 2020) when by reducing scalability and content availability. Free-riding on these platforms is not only limited to P2P platforms; for instance, eBay is also having this kind of problem. Online market platforms such as eBay offer the platform for trading for the buyers and sellers. In majority of the cases, neither the buyers nor the sellers have ever met each other. Hence, this will always give room on possible cheating or under performance. That is why eBay has a reputation system that operates on the principle of ratings which is aimed to mitigate this. The reputation of a buyer or a seller is determined by the user's rating of his opposite party at the completion of each transaction. As mentioned by them users benefit from this reputation when deciding which transactions to make (Gupta, et al., 2021). The selfish behavior of others or of the freeloaders decreases a system's overall performance. This would also deal with the problem of selfish peers or free riders in the network, which motivates the network to have good performance (Ansari et al., 2021). Peer-to-peer networks and the way to address the free-riding problem have been considered from different perspectives over time. Micropayments, reciprocity and reputation systems are the three main types of incentive-based systems that are used to tackle free-riding behavior (Alotibi et al., 2019). Nevertheless, free-riders pose the major threat to the P2P system implementation since it makes the system subject to resiliency problems. Such undesired phenomenon can be reduced by employing any of the previously mentioned incentive driven methods that gives negative punishment to free-riders and motivates peers to participate in the system (Kishor & Niyogi, 2023). The study under consideration suggests a viable incentive-based mechanism that utilizes micropayment techniques in order to discourage free riding in peer-to-peer networks, while at the same time increasing cooperation among peers and eventual system robustness. The rest of the paper is structured as follows: As for section 2, it presents the literature review. Section 3 is about methods and techniques, while Section 4 presents the results and discussion. The conclusion and possible future research directions are given in Section 5.

II. Related Works:

Numerous studies have attempted to prevent or decrease free riding in peer-to-peer networks to fulfill the purpose of a fair distribution of text, music, video files, channel capacity, or processor power. Here comes a review of the some of the literature in this domain.

Yousafzai et al. in (Yousafzai et al., 2021) have proposed the implementation of a bitcoin (BTC)-based crowdsourced peer-to-peer content distribution network (CDN). A crowdsourced content delivery system employs seeds from a sub-network of seed-supplying peers by their contributions to total CDN content distribution capacity. The principle used for providing a catering service based on a crowdsourcing network that was blockchain currency-based and smart-contract-based, generated revenue for its users. A crowdsourced content delivery networks model has the peer nodes encapsulate into container and provide opportunities for CDN service providers to monitor users' contribution and guarantee that CDN content is protected in the separate containers.

The idea of self-motivated reward schemes employing the block-chain to provide cryptocurrency for P2P applications based on decentralization with the users awarding each other for collaboration was presented by (He et al., 2018). According to this system, users who participate in a successful task are given rewards. We found that using a secure validation model and a pricing approach in an incentive mechanism can counter any selfish behavior or collusion between participants of the BlockchainP2P system, users and miners. Both the effectiveness and the security of an incentive mechanism were proven by conducting a game theoretical analysis and the evaluation study of it. The authors (Liu et al., 2024) developed blockchain technology and reputation assessment system for healthcare services. Solution provides the comprehensive assessment of the reputation with feedback for the rewards to the participants of the blockchain consensus and to stop the attempts of dis-service in the healthcare system. In addition, a study carried out by (Rahimzadeh et al., 2017) demonstrated SVC- TChain which is a strategy for curbing the act of free-riding. The technique is a P2P video streaming scheme that is based on scalable video coding (SVC), and T-Chain reward mechanism is used to counteract the free-riding

problem. The method brings T-Chain analysis and offers an analytical framework to solve SVC patch selection with multiple video layers. This framework in fact supports in choosing the best parameters of both static and tracking controllers and in turn helps prevent violations of the piece selection rule. SVC-TChain is more efficient than single-layer constructs of BiTos and G2G in peer-to-peer video streaming as our experimental results demonstrate, even with the user behaving in bad faith.
Some other researchers argued that a reward-oriented security strategy that elicits higher seeder activity with lechers participating actively in the network was the way to go. The strategy will keep the malicious flakes from the network by excluding them, and at the same time, the good ones will be fairly compensated. This is one of the BitTorrent network flaws. In addition, by joining encryption methods this architecture an encrypted channel, which resistance to eavesdropping, was created similar to privacy-protected communication network (Berenjian et al., 2019).

Alongside this, (Zhang et al, 2020) built a game model to evaluate the upstream and downstream teams' strategy decisions. Thus, we can observe how sharing strategy among research and development teams affects the interactive effect of the common coefficient of technology gained through free-riding. An elaboration of a remuneration can separate overhead costs, and can enhance the technology sharing motivation, giving policymakers more options in creating and appraising manufacturing innovation programs.

The newly created model called DNS Cache Resources Trusted Sharing Model to increase the reliability of DNS resolutions was presented which forms a more secure chain of trust. The consortium blockchain is utilized to secure the DNS cache credibility from unauthorized manipulation and access within the peer-to-peer communication network. A node credibility evaluation index is suggested in addition with trust-based incentive mechanism as a part of the DNS cache sharing model to address free-riding problem and enhance the system's reliability (Yu et al., 2020). Moreover, authors from (Ojo et al., 2020) suggested an economic-based mechanism for peer-assisted streaming called AyoPeer; this method penalizes free-riding. The basis of the strategy is the yoruba traditional game popularly called Ayo. A major objective of the AyoPeer system is to enable peers to distribute videos and exhibit their neighbor's models of actions (if they are sharing or hoarding their chunks). The super peers handle resource exchange and making sure that cooperating teams of children pairs continue to receive their requests. When a child's score hits the set benchmark, bigger peers keep an eye on it. They are, consequently, tagged as free-riders and they are denied access. Non selected peers are thus unable to refresh, get chunks or ask for shares.

The system was created with three goals in mind: efficient network transmission, student-centered learning mode, and resource distribution system. What was revealed is that along the growth of the population of kid peers the scale of AyoPeer also grows. A whole video chunk was delivered by the peer who cooperates. Also, the results showed that the AyoPeer framework is robust and competent with free-riding. (Chengzhe et al., 2017) offered a secure incentive scheme for highway vehicular ad hoc networks to guarantee the fairness and reliability of cooperative download. To achieve this, a reputation-based network was established. This network recognizes and encourages good vehicles and punishes the bad ones. Motivated attacks of the kind vehicle assaults, i.e., rejection/removal attacks, free riding attacks, and denial of service attacks are resisted by the aggregating signature and symmetric cryptosystem. But, having moderate communication and computation the SIRC experienced high download success-rate and low average delay on a large scale basis when focused on.

(Caciano and Carla, 2020) Trustless features have been analyzed in diverse systems in order to develop a mechanism for enforcing collaboration. They put the problem of selfish behavior in context in networks made up of routers belonging to diverse participants: the community, D2D, and vehicular networks are also included along with the alternatives to DTN. The authors observed that the actions of uncooperative users from time to time contributed to erratic communication and, subsequently, lower MANET user confidence. They facilitated credit- and reputation-based pre-blockchain incentive mechanisms for data forwarding, and a game theory method as well.

(Martijn and Johan, 2021) ConTrib stands for universal approach to maintaining fairness in decentralized apps, taking under the effort done by peers. Parties maintain individually controlled and tamper-proof records. Indexes contain records done by a peer, and include links to other records. In Con Tribe a tamper is done to the records in the personal ledgers without permission. It is recognizable with the random exchange of records between peers and the verification of consistency of the incoming records against known records. (Machado, et al 2021) proposed HARPIA, a credit-based incentive mechanism for data forwarding in community networks, with the goal of reducing selfish conduct and free-riding. Unlike other incentive schemes, HARPIA does not require a third-party security module. To settle individual cryptocurrency debt on an Ethereum smart contract, it uses a distributed accounting scheme (DPIFA) to estimate the equilibrium of data forwarding contribution and consumption of each network router. Under a constrained m-of-n multiple signal threshold, this suggested technique is acceptable for community networks with up to 64 infrastructure routers.
A solution to the free-riding issue was proposed, involving a social planner who serves as the decision-maker for individual agents. The free riding problem was represented as a constrained optimization problem. An algorithm known as the artificial bee colony algorithm is utilized to address the issue. The empirical findings demonstrate that each peer gives their maximum potential and obtains an equitable profit share (Kishor & Niyogi, 2023). An adjusted free-market-inspired strategy was presented to address free-riding. The concept views resources as commodities with fluctuating prices

determined by supply and demand levels. Peers own wealth that can be augmented through resource provision and depleted through consumption. The experimental findings show that the suggested method can enhance fairness without reducing success rates (Kurdi et al, 2020). Leveraging on the above literature, it can be deduced that the incentive-based mechanism, more importantly micropayment or monetary-based approach are more suitable for tacking free-riding in peer-to-peer network and by extension in blockchain infrastructure, Hence, a robust and effective micro payment strategy is proposed in this study, which is suitable for addressing free-riding or other challenges mimicking free-riding behavior.

III. Methodology:

The strategy presented in this section includes techniques for avoiding free riders in the network. The success of the proposed approach very much will depend on the combination of the work of the super-peer and the coin tracker. Everyone taking part in this network will be paid utilizing this gratifying currency as a reward for resourcing the network in the process of cooperation. Cooperative peers that work successfully towards the content delivery mission shall be rewarded while uncooperative peers will not receive their rewards. The content to transition over the network in the case of this coin model is a media file, such as a video or a song, from the server to a super-peer on the network. Then, the single file is split into two separate and the first one returns to the parent node while the second one is sent to the child peer. On the network, every super-peer keeps a population that is responsible for tracking resource consumption and redistribution. The monitor will audit the distribution of the currency and detect the peers who opposed the policy to make sure that those never participated in the currency.

A crucial aim of the coin model network consists in disruption of free-riding and filtering of the least contributing nodes. The topology model proposed consists of a server, super peer, and children peers as represented in Figure 1. The super peer hosts the content media, whereas the child node recently acquires the content and then distributes the material. The network model consists of bidirectional architecture capable of file sharing between child and super peers. The bottom floor is headed by a peer group at the helm of which are upper-ranking peers who are responsible for dealing with and reporting the network status every now and then. First level scalability limitations have been removed by the super peer in the overlay; it provides connectivity to the others in the logical overlay.

The study suggested the use of a Coin Crediting approach as an incentive structure which will give rewards to peer children based on the success of streaming sessions. This will so increase the engagement of peers, hasten the punishment of those gains without giving back, and surely provide a foundation for creative peer-to-peer interactions. The central server sends the videos to super peers, which are the peers with high bandwidth or dedicated servers providing the distribution part. The Super peers serve as video replicas of the server and use tools that help in the surveillance of the behaviors of their child peers. The task of sharing videos among the child's peers can mean sharing with other peers, new peers or super peers. The downloading technique for the proposed coin model is presented in Algorithm 1, it shows the procedure of peers requesting for a specific video or audio file contents and how it request is granted to each peer.

Algorithm 1: Downloader

Input: file or file to download

1. Cw ← getCwDedicated ()
2. Download Info ← new download Info (node, bw, file)
3. pp ← new list () // participant on the network
4. pp ← receiveSources() // sources found is stored in pp
5. send (download Info, pp)
6. mng ← sessionManager()
7. if (status == ko) exit
8. else
9. taskDone ← 0
10. lastAck ← 0
11. receiveFile.start() // this will receive data messages from participant
12. exit()

Output: success Message, downloaded File.

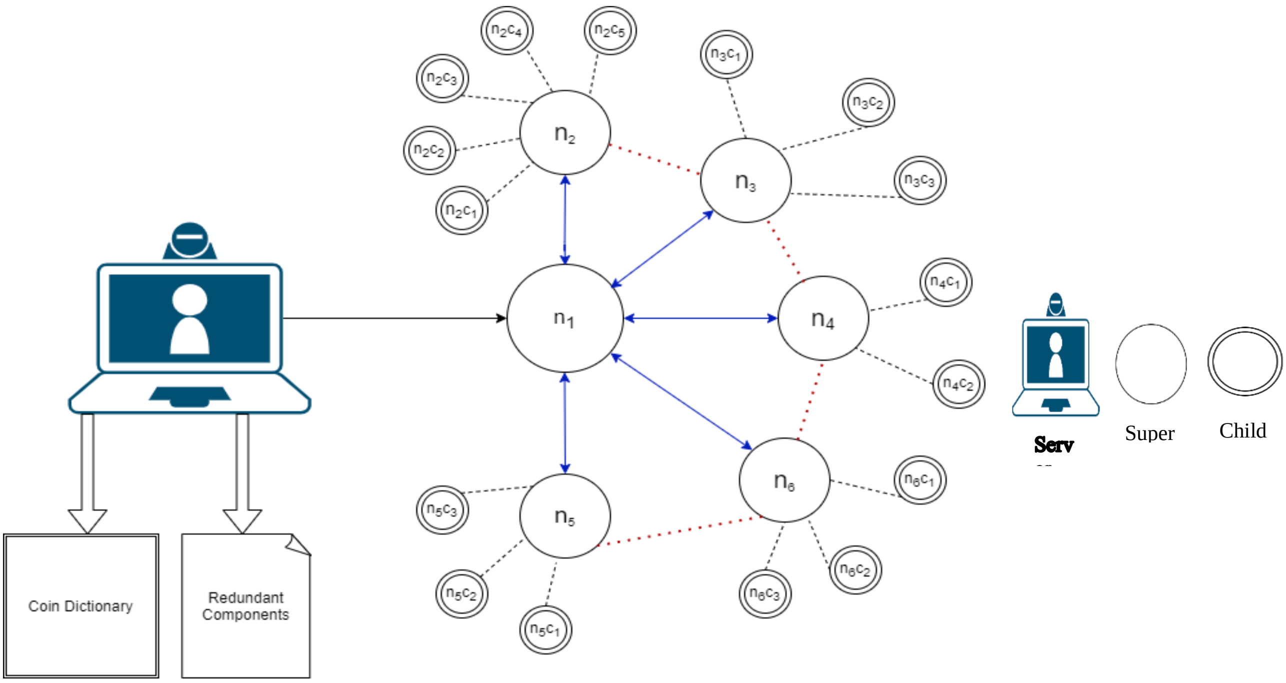

Figure 1: The Proposed Coin Model Topology

As mentioned earlier, the scheme monitors peer cooperation in the system; this is achieved by keeping track of all the peer activities for each streaming session. The peer monitoring process is represented in Algorithm 2, which keeps records of all the peer's activities, such as receiving and sending video or audio files. The procedure listed in Algorithm 2 makes it easier for the enhanced coin model to track if there are free-riding peers in the network since all activities of the peers are monitored. The coin manger pseudocode is presented in Algorithm 3 which gives reward to the participating peers.

Algorithm 2: Peer Cooperation

Input:
D_i ← download Info
T_d ← task Done
mgr ← message
1. start ()
2. if (req == receive ())
3. do receive (D_i)
4. send (mgr)
5. receive (task)
6. task done ← 0
7 loop
7. send (data, mgr)
8. task Done ← task Done + data
9. if (task Done == task. total())

Algorithm 3: Coin Manager

Input: P_i ← downloader Peer
P_o ← manager
Z ← file to download
1. start ()
2. receive (P_i, Z)
3. for all node p in pp
4. send (z)
5. loop
6. receive (Coin_Offered, coin_offered)
7. if (coin_offered > 0)
8. coin_offered ← $P_i + P_o$
9. exit ()

Output: coin Reward.

IV. Results and Discussion:

The section discussed the simulation environment and the simulation results proposed Coin-based incentive P2P network topology. The simulation is implemented using JAVA programming language and the BitTorrent protocol with Eclipse integration development environment. Java was used in simulating the coin model peer - to - peer topology because of the support they have for networking and the already available simulating environment which Java provides for networking. It is object-oriented (class-based), high level, generic, imperative and functional programming with fewer implementation dependencies.

In order to simulate the Coin based incentive model, the following subjugation are applied in other to measure the performance of the system:

-There is a single server
-There are six (6) super peers
- The child peers are assumed to have zero coin at initial stage.
- The child peers are rewarded coins based on how they participate in the simulation.
- Once the child peer value is set, no other child peer can join the simulation.
-Number of files in (kb) to be shared before simulation takes place is set.
- The simulation time is set in seconds.
- Super peers are set before simulation.
- Child peers are set before simulation.

The parameters used for the simulation scenarios are presented in Table 1.

Table 1: Simulation Parameters

Variable	Value
Child Peer	500, 1000, 1500, 2000, 2500
File size in (Mb)	150
Split Size (Kb)	0.3
Minimum start up delay(ms)	0.1982
Maximum start up delay (ms)	1.5253

The metrics used to measure the performance are, fairness index, robustness and scalability, download time, number of blocked peers. Fairness index is an evaluation of the total number of successful downloads to the total number of successful uploads. The fairness index should be closer to one and should not exceed it. This is to ensure that the number of uploads should not exceed download and vice-versa which makes the network fairer. Networks. The download time is the time in milliseconds of the total number of downloads that has been made after successfully blocking peers during simulation. It is the time taken for the successful peers to get the full requested file before the end of simulation. The number of blocked peers is the measure of the captured peers that were not participating on the network. The captured peers did not complete their download before they were blocked. The robustness and scalability of the simulation is the measure in percentage the number of peers that successfully complete their download after successfully blocking uncooperative child peers.

The fairness index results obtained for different simulation scenarios are presented Figure 2. The results revealed that the system achieved an average of 83% fairness index when the child peers are between 250-1000. However, the value increased to approximately 90% as the more peers join the network (1500-2500 peers). This shows that the enhanced coin-model is suitable for dynamic environment and can effective manage distribution of resources in peer-to-peer. As depicted in Figure 3, the average time ranges from 0.003ms to 0.0015ms. However, higher download time was observed at less 500 peers as compared to 500 -2000 peers which achieved download time less than 0.002ms,

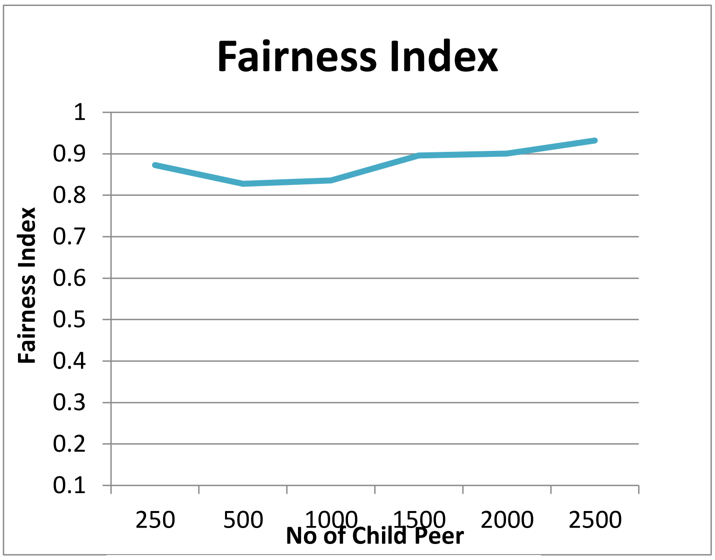

Figure 2: Fairness Index Results

And the download time suddenly increases when the peers increased to 2500. This consistent download time behavior exhibited with 500-2000 peers shows that the coin-based model is capable of utilizing the best features of P2P networks. The blocked peers results as presented in Figure 4 shows a constant increase in block peers as the number of child peers increases. This behavior further validates that the coin-based model is capable of curbing free-riders in P2P networks. Finally, the robustness and scalability results as shown in Figure 5 also confirms that the coin-model is capable of handling flash crowd and peer churn in the network.

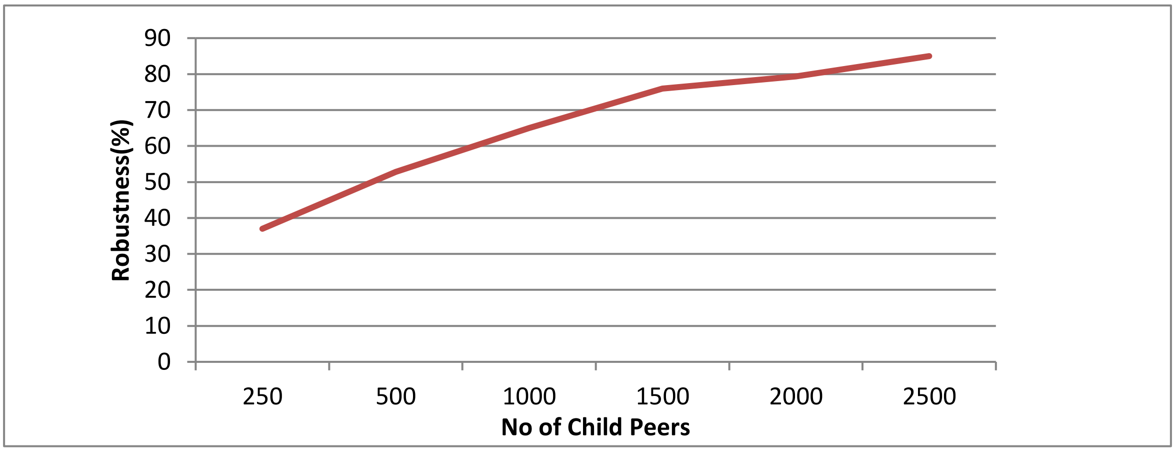

Figure 3: Network robustness/scalability in (%).

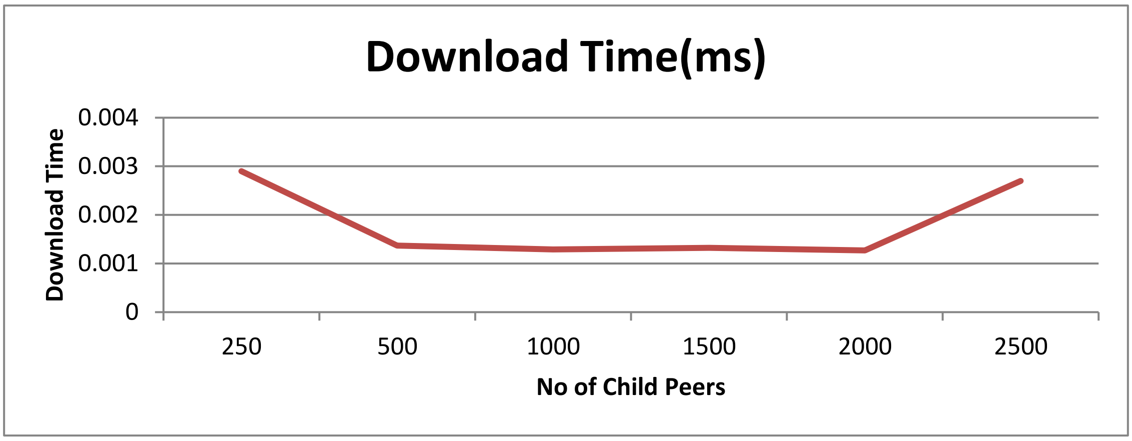

Figure 4: Download Time Results

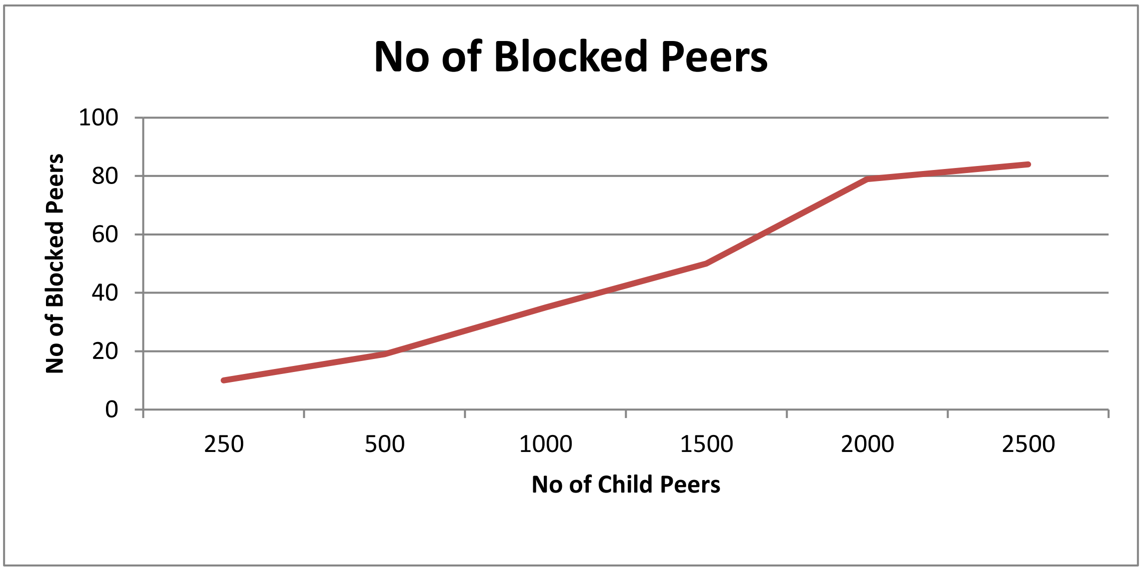

Figure 5: Blocked Peers Results

V. Conclusion:

To discourage free-riding, a new network protocol framework with the Coin Model Algorithm is recommended in a peer-to-peer network. It was noted that the performance metrics of the system got better and better each time the number of child peers grew. The concept of the main idea is to transfer the video files among the peers and watch their actions whether they prefer sharing or hoarding some of them. Supers participate in resource swaps to guarantee that kid peers get their requests. The Super peers review the scores of the child peers. A score falling below the threshold marks the child's peer as a freeloader and bars him/her from the group. Excluded children's peers cannot request nor receive data segments. Coin-based incentive model algorithm is running on Eclipse/NetBeans IDE using Java pointing to its efficiency to free-rider. The presented method exhibited a great tolerance to message drop and delay.

The Coil-incentive mechanism algorithm does not allow for the designation of some Child peers as Super Peers based on their bandwidth or a possession of a certain number of chunks. The free-rider detection threshold is a decisive metric that shows if a node is a free-rider or not. The default value can be modified within the simulation settings. A variable threshold may be a better method of detecting free-riders in dynamic P2P networks. A study of environmental variability may be needed to determine when this threshold should be adjusted. This may be investigated in future research

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