VidAdChain: An innovative blockchain approach for digital video ad serving and management

Sartzetakis Nektarios
NEMO SERVICES , Apostolou Pavlou 33, Korinthos, 20131, nektarios@nemo.services
Dermenoudis Konstantinos
NEMO SERVICES , Greece, Apostolou Pavlou 33, Korinthos, 20131, kostasd@nemo.services
Vafeias Michail
NEMO SERVICES , Greece, Apostolou Pavlou 33, Korinthos, 20131, michalisv@nemo.services

Abstract:
Digital advertising from its humble beginning at the end of the 20th century has grown into a multi-billion-dollar industry. Along with its increasing size and worth, the industry is facing challenges of increasing severity. Securing the validity and safety of transactions within the digital advertising ecosystem, protecting the personal data of advertisers, publishers and consumers and minimizing the effects of intermediaries and fraud are currently the principal factors that threat the value of digital advertising. Blockchain, an emerging technology first adopted in digital currencies and financial transactions, is gaining attention as promising solutions to the above-mentioned challenges. Blockchain is founded on distributed ledger technologies, incorporating advanced security features, such as cryptographic signature technologies and cement transparency and trust between advertisers and publishers. With Blockchain the need for intermediaries is limited, all campaign and personal data of the viewers are stored encrypted in the blockchain, providing transparency to the advertising model and, consequently, increasing the value of advertising across the ecosystem. In this paper we present an innovative approach for developing a blockchain enabled ad serving and management service, named VidAdChain, which we develop as the next gen solution of the established in the Greek advertising market, Vidads© video ad server. The service targets the digital video advertising segment of the market, due to the increasing significance of video in the digital advertising mix. Nonetheless, the core features of the present technological solution can find applications in all forms of digital advertising (banners, rich media, native ads etc.). Our research demonstrates that blockchain technology can effectively mitigate ad fraud by recording ad-related data on an immutable ledger, providing accurate and reliable information about ad performance. Moreover, the decentralized nature of blockchain enables real-time data access, automated transactions, and streamlined payments. However, challenges related to scalability, user privacy, and regulatory compliance need to be addressed for widespread adoption. This paper concludes that developing a blockchain video ad server has the potential to revolutionize the advertising industry by improving the integrity and efficiency of video ad serving, and further research and development in this field are crucial for its full realization.

Keywords: *Digital Advertising, Video Advertising, Blockchain, B2B Marketing, Innovation*

▪ Introduction

Global marketing spending to digital advertising has increased rapidly over the last years, leading to an estimated 567 billion dollars for 2022 (Cramer-Flood, 2023). With the emergence of mobile technologies, the penetration of internet in the global population (yearend estimates 2021) has reached a new maximum of 63% (ITU, 2021). As is the case with any rapidly evolving and unregulated market, challenges are on the rise. Most of them are owed to its convoluted and opaque supply chain. These issues, being inherent in the core of current operations, affect every member of the advertising chain: publishers, advertisers, and consumers. B.R. Gordon et al. have recently highlighted four major inefficiencies of the digital market: ad effect measurement, frictions between and within advertising channel members, ad blocking, and ad fraud (Gordon et al., 2020).
Starting in reverse order, ad fraud is currently one of the most challenging and far-reaching problems of the digital advertising industry. Put simply, the term digital advertising fraud refers to a group of practices that misrepresent advertising inventory or utilize machines to mimic human behaviour with the goal of "*stealing*" advertising budgets. Not only is advertising fraud difficult to quantify but it is presumed to be widespread on the internet. A recent report has estimated that about 14% of PPC ad spending globally is invalid and most likely attributed to ad fraud schemes. Sadeghpour and Vlajic recently reviewed the current state of the usage and impact of bots in click fraud and provide an account of the most recent threat mitigation strategies available

(Sadeghpour & Vlajic, 2021). They concluded that contemporary click-bots can replicate human-like interaction behaviors and consequently traditional, interaction-based user behaviour analysis is highly unlikely to detect them. Furthermore, they highlight the inefficacy of solutions currently available against complex click bots in the real-world that are evolving and mutating constantly. Finally, they too suggest that the most severe challenge in defending against ad fraud can be found in the ad industry's lack of transparency and accessibility of information in the ecosystem.

Tightly bound to the issue of fraud is also the next major challenge of the market, ad-blocking. Ad blocking software has been established in the digital ecosystem with 290 million active desktop users using ad blocking solutions (*2022 PageFair Adblock Report*, 2022). The reason behind this increase has two main explanations. Digital advertising has become the industry of personalized ads. Through tracking technologies, advertising services can collect data about the users' online behaviour, besides demographic or geolocation data. Third-party data brokers can in fact aggregate data from several sources and sell them to marketeers. According to a study performed by N. H. Brinson et al., it is exactly against this sort of personalized advertising that consumers that use ad-blocking software want to protect themselves (Brinson et al., 2018). Not having an established relationship with third parties increases insecurity and raises data-protection concerns and favors the use of ad-blocking. In addition to the above, webpages overpopulated with ads are deteriorating the users' experience. In a relevant study performed by B. Miroglio et al., it was shown that ad-blocking increases significantly active time spent browsing and number of webpages viewed (Miroglio et al., 2018). Besides the benefits to users, ad-blocking means revenue losses. For example it is reported that in 2016, estimated global loss from the use of ad-blocking was $1.4 billion (Respati & Irwansyah, 2020). To summarize, personal data protection and the intrusiveness of digital ads, in combination with ad-fraud schemes constitute the major challenges faced by the industry, the state of which is further contributing to their expansion rather than minimizing it.

The current digital advertising ecosystem is overly complex in nature, including countless advertisers, publishers, ad networks, agencies and affiliate networks. As a result of its size and of the absence of a widely adopted system for targeting online audiences without compromising sensitive information and identity data of these audiences, the industry has become dependent on the Meta/Google duopoly. These corporate giants, absorbing more than half of the digital ad spend globally, have more than once been accused of malpractices concerning data privacy and monopolistic behaviour (Colangelo & Maggiolino, 2018). These companies have been exploiting their privileged market position and trying to present themselves as de facto privacy regulators (Geradin et al., 2021). Moreover, middleware and intermediaries are absorbing increasing amounts of digital ad spend, pressuring the ad spending capacity of small and medium enterprises. Consequently, if the current status of the ecosystem persists, digital advertising will inevitably reach a point of devaluation, which could have dramatic effects for all actors in the value chain.

The above analysis more than highlights the pressing need of the industry to invent new technologies and frameworks and secure brand safety, consumer privacy, measurement, market power and transparency. Blockchain is one of the technologies with disruptive potential to achieve these goals.

In this article we first present some fundamental features of blockchain technologies and highlight how they directly address the issues of privacy, transparency and measurement validity. We then go on to introduce VidAdChain, a concept for a blockchain based video advertising serving and management tool. In this section we will present the ad buying and serving operations that revolve around the concept of Smart Contracts – digital entities that include all the advertising campaign information needed to execute advertising campaigns with Blockchain capabilities. Finally, we will present the challenges our group has already identified in the course of the research and how we plan to address them in the course of our research.

▪ Fundamentals of blockchain

▪ *Blockchain as Distributed Ledger*

Blockchain is defined as a decentralized network of peer nodes, within the boundaries of which the data and transactions carried out between these nodes are recorded. In this particular network, data is registered and stored in packets (Blocks), which are connected to each other, creating a chain of Blocks. A Blockchain network is distributed peer-to-peer, meaning that no one person (or computer) within the network is superior to another. All computers participating in the network have access to it and record transaction and communication data, each keeping a copy of the record file, which ensures the security and transparency of transactions (Gorkhali et al., 2020; Lashkari & Musilek, 2021). The process of creating and preserving the file is defined and controlled by a set of rules called a consensus protocol (Lashkari & Musilek, 2021). The rules are set by the network participants and participation in the network automatically constitutes acceptance of them.

Each transaction, before being registered in the Blockchain, is checked by the computers of the network based on the rules of the protocol. Once verified and approved, it is entered in the file according to the chronological order in which it was carried out. The file created and shared among a large number of users is encrypted and does not allow changing the records already registered in it, while the absence of a central administrator increases the reliability of the system, making it difficult to manipulate. In practice the log file acts as an

immutable record of transactions that does not require validation of the authenticity and integrity of the data by an external authority (Zheng & Lu, 2021).
The information contained in a Blockchain can be about an asset or intellectual property, even a voting system or legal documents. In the case of the technology presented in the scope of this research, the information that needs to be stored in a Blockchain is data of digital advertising campaigns. Hence, the primary goal of the research is to describe how such a Blockchain ad management system needs to be designed and developed.
According to the above, the most important aspect of a Blockchain technology for the digital advertising market is to find a means to describe the advertising transaction as a set of rules that can be handled and verified digitally by the different nodes (advertisers, publishers, agencies etc.). This is achieved by Smart Contracts, digital entities that will be briefly described in the next subsection.

- ***Smart Contracts***

Blockchain technologies make possible the creation and execution of Smart Contracts, which offers the perspective of developing a peer-to-peer market in the near future. A detailed description of the technological and technical properties of smart contracts has been performed by Z. Zheng et al. (Zheng et al., 2020), while a critical review of the main technological and legal issues raised during this early period regarding the applications of smart contracts has been done by E. Mik (Mik, 2017).
A smart contract is a digital protocol whose purpose is to verify or facilitate the negotiation or execution of an agreement. Smart contracts allow trusted transactions to be performed without the need for a third party. Transactions are irreversible and simultaneously tracked. It contains rules that participants have agreed to adhere to in their interactions with each other. When the predefined conditions of a smart contract are met, the contract is automatically activated. Its behavior is based on the algorithms on which it is built. Blockchain platforms that support smart contracts are also referred to as programmable blockchains.(Oliva et al., 2020). The operation mode of smart contracts in the context of a Blockchain is briefly presented in Figure 1.

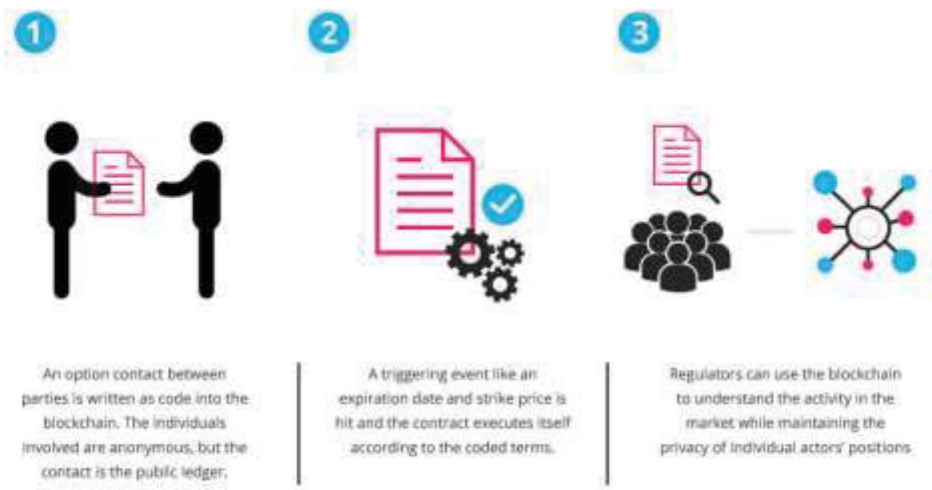

Figure 1. Core features and operation procedure of a Smart Contract in Blockchain applications

The biggest advantage of smart contracts is the fact that they dramatically reduce transaction costs. A smart contract defines the rights and obligations that participating members agree to abide by. Compliance monitoring and enforcement of each member's contractual right are handled by a computer network. In this way, it is possible to enter into contracts with members for whom there is no previous solvency information. In addition, it becomes possible to carry out transactions involving amounts that would not justify the cost and burden of concluding agreements if they were to proceed in the traditional way. Other attractive features include their continuous operation and that they do not impose time or location-related availability restrictions. Smart contracts are self-verifying, self-executing and unbreakable. Their typical use cases are situations in which the parties wishing to enter into a contract do not know each other and do not necessarily trust each other. They can bypass intermediaries and through Blockchain provide the required security.

- ***Security and Consensus***

As in a Blockchain network, there is no central entity, so there is no one to control which transactions will be stored in the chain of records, it is necessary to have a consensus algorithm or protocol, based on which the participants will verify and approve information before it is entered into the system. Consensus algorithms must be invulnerable to any malicious action. The two most well-known consensus algorithms are Proof of Work and Proof of Stake.

- **Proof of work:** In Blockchain transactions are grouped into a block. The hashing of the previous block acts as a unique identifier and is added to the current block, which connects all blocks together forming a chain. The internal consistency of transactions in each block can be easily verified by an honest client. For this reason, the nodes of a Blockchain network perform the Proof of Work algorithm to create a new block. This algorithm requires a node (also called miner) to pick a random number called a nonce, add it to the list of transactions that make up a block, hash the block and check whether the resulting hash starts with a specified number of zeros. If not, it picks a new random nonce number and tries again. The miner's computer processor will generate many hashes until it succeeds, making it a direct CPU-level problem. The Proof of Work algorithm is based on the principle that no node in the network should own more than 50% of the total computing power, as it will be able to effectively control the system (51% attack). When the network is managed by a large number of users, then this is almost impossible.
- **Proof of stake:** The Proof of Stake algorithm replaces the competition of Proof of Work by randomly selecting participants, who will take part in the process of verifying transactions in a block and its subsequent entry into the Blockchain. In this particular algorithm, interested parties who want to participate in the validation process are required to "lock" a certain amount of coins in the network as their stake. A stakeholder of a given Blockchain is a person who holds some native coins of that Blockchain, and staking refers to a shareholder's ownership of such coins. The size of the stake determines the chances that a node will be selected as the next validator, i.e., the higher the stake, the higher the chances. In theory, validators with higher stakes are more likely to be chosen to validate their reputation. A special case of the Proof of Stake consensus is the so-called **Proof of Authority** (PoA). On PoA-based networks, only approved accounts can validate transactions and blocks. These accounts are also known as validators. Validators run software which by definition allows them to record and verify transactions in blocks. The process is completely automated, and validators do not need to be constantly monitoring their computers. It, however, does require maintaining the computer (also called the authority node) uncompromised.
- **VidAdChain: A blockchain enabled video ad serving and management tool**

VIDADCHAIN is an innovative research project that attempts to apply the principles of Blockchain technology to the design of digital video advertising scheduling, display and control software that will have increased capabilities to address the inherent pathologies of the digital advertising ecosystem (data protection, fraud, dominance intermediaries). In more detail, VidAdChain aims to:

i. *Provide an environment for secure and automated digital advertising transactions*

   With Smart Contract technology regulating the terms of the transaction and the Blockchain architecture securing the validity of the details of any advertising contract, the technology designed for VidAdChain can revolutionize digital ad operations.

ii. *Provide ad delivery data that are validated through the Proof of Authority protocol and provide a successful antifraud measure*

   As mentioned earlier, the PoA consensus protocol implemented in VidAdChain's architecture, supported by Artificial Intelligence algorithms that can detect click fraud patterns, will ensure that advertisers can have higher return on investment on their digital ad spending. At the same time, sources of fraud can be detected automatically, giving the opportunity to restrict the activity of malicious players in the digital advertising ecosystem. Most importantly, any party interested to join in the Blockchain can act as a validator, meaning that the data will not only be validated by the authority node of VidAdChain, but also from individual third-party services or even from individual advertisers or publishers, in a truly open and transparent system. In this way, while our proposed solution utilizes a private blockchain network, the data stored in the blockchain ledger will have originated through third-party validators who have access to them indefinitely, making VidAdChain a truly transparent ad serving solution.

iii. *Provide increased encryption and safety of consumer and ad delivery data*

   All transaction, ad delivery and consumer interaction data are stored in the blockchain which operates with cryptographic technologies. This makes all data practically impossible to obtain or manipulate as there is no single point of failure in the system.

According to the above, the innovative solution proposed is expected to have significant benefits in the future, especially for the advertising expenditure of the tourism market, which is experiencing high losses due to digital advertising fraud and the dominance of intermediaries.

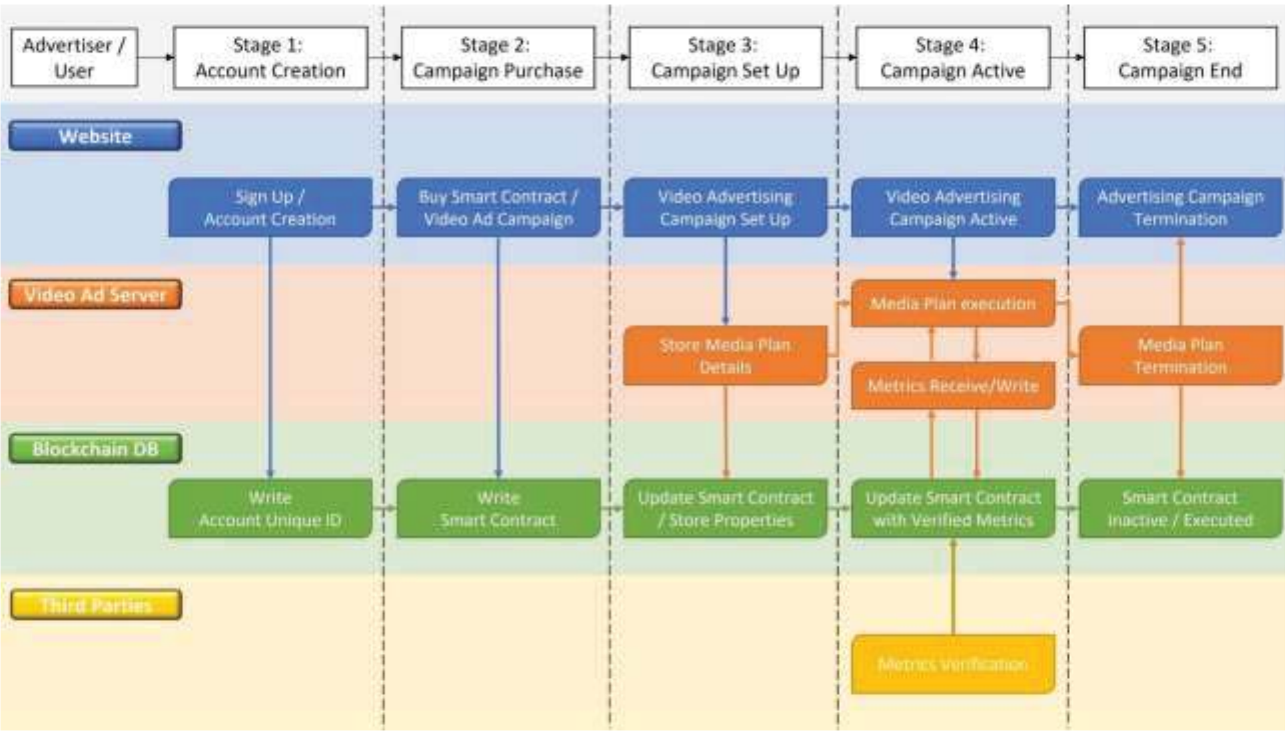

Figure 2. A design of the function layers of the complete model for the advertising solution. From the marketing website to the blockchain database, the use of smart contracts and the campaign statistics interface.

At this stage of the research, different layers of the software development process have been defined and the corresponding action map for the use of the software has been designed. Figure 2 depicts the layers and actions taking place by a hypothetical user – an advertiser that wants to place an ad in our service. By following this action map, the core features of blockchain and its capabilities can be better understood.

In more detail, all actions and interactions of the user/advertiser with the service, the management and monitoring of the course of his advertisement as well as his billing and pricing for this display, take place in three axes or three levels of implementation: (a) on a website, which constitutes the user interface with the service (UI interface), (b) in a video advertisement server (Video Ad Server) and (c) in the blockchain database that records, stores and provides access to all data (commercial , finance, metrics) that are traded all the way. These three levels constitute a closed system, with each layer communicating with the others, while the advertiser is enjoying an orderly and reliable display, having as much control as possible over the renewal of its properties. Finally, there is always one more level, outside the system, where various services providers can interact with the blockchain, performing various functions such as independently validating data and statistics, reading the data in the advertising transactions, etc. This open Application Programming Interface (API) architecture that allows access to the blockchain from third party validators is an unprecedented proposition for the development of an ad server. Its originality and innovation lie in its potential to offer transparency in data that cannot be manipulated (in Blockchain no transaction can be erased).

From the above analysis, it is easy to see that the differentiation of the studied solution in relation to the existing ones is at the level of the database. As, as mentioned above, Blockchain is essentially a database shared among the users of a Peer-to-Peer network, a system architecture should be developed that allows (a) the "sharing" of the database among its nodes network, (b) the ability to confirm the data that is being exchanged in immutable ways, before it is recorded in the common ledger of the blockchain. A second important differentiation lies in the form in which the data of an ad or campaign must take in order to be entered into the Blockchain and subsequently updated through it.

The way to achieve this is through the use of Smart Contracts that fully and quantitatively describe the properties to be recorded and which conditions must be met in order for the contract to be considered successful.

Turning now to Figure 3, at its upper part, the user's journey in distinct stages, from registration to purchase, execution and completion of an advertising campaign is shown These stages are the following:

- **Stage 1 – Account Creation:** This is the registration of the user to the service. This stage only takes place the first time the user uses the service. Automatically upon confirmation of registration, it obtains a Unique ID which enters the Blockchain. This Unique ID represents his account in terms of transactions that will be recorded on the Blockchain in future campaigns.

- **Stage 2 – Campaign Purchase:** The now registered user can purchase from the commercial website an advertising campaign (an ad package), with specific elements/features. When purchase of the ad package is confirmed, a Smart Contract is created and entered into the Blockchain, which encodes as properties the specific elements of the package. These are objects of the future advertising transaction, e.g., campaign duration, number of creatives, available display budget, etc.
- **Stage 3 – Advertising campaign configuration (Campaign Set up):** The user through the UI enters the specific data that will determine the specifics of the advertising package purchased. She defines the start and end date of the campaign, uploads the video ad files into her account and defines the targets of the campaign. The data that are part of the smart contract, after their final registration by the user, are entered into the Blockchain. This process constitutes an update of the smart contract's properties, and their saving must be confirmed.
- **Stage 4 – Monitoring of an active campaign (Campaign Active):** When the campaign is ready to launch, VidAdChain's Video Ad Server is called upon to validate the first ad view. Practically, this procedure constitutes testing of the functionality of the Smart Contract. At this point it should be noted that the uniqueness of a view, which is the fundamental transaction within the context of the smart contract, is ensured by the existence of the property called "Unique View ID." The Unique View ID is a unique encrypted ID that corresponds to a unique view that will be made on a certain player and on a specific publisher's webpage. All the properties contained in the smart contract are connected to the Unique View ID and the information concerning them (statistics, measurements, etc.) that will be recorded in the Blockchain are part of it. Practically every view of the video advertisement that takes place, on every player and on every page of a publisher has its own Unique View ID and in this way the reliability of the produced results of the advertising campaign is ensured. Once the first view is validated the campaign is considered active. VidAdChain's Ad Server, based on the Index, Inventory and characteristics of the campaign, initiates the display to various publishers and the ad placements they have available for advertising. Viewing is done using the Unique View ID and campaign results, as smart contract transactions are stored on the Blockchain. The process of trading, storing and confirming new blocks is constantly evolving for the duration of the campaign.

  As new blocks are confirmed on the blockchain, there are constantly improved versions of campaign statistics. The Ad Server receives data from the Blockchain about the current state of the campaign and constantly recalculates the Inventory and refreshes the Indexes. Accordingly, the databases used for real-time recording of the campaign and recording of the overall campaign metrics communicate with the Blockchain layer and retrieve the latest data for the campaign. This is where the essential difference and revolutionary function of Blockchain emerges. For each confirmed transaction (ad view) there is a Unique View ID whose validity is ensured by rules that are constantly checked by an AI system. Consequently, only validated, i.e., human generated transaction data are stored in the blockchain, and the act of validation can be performed and confirmed by any validator that participates in the blockchain. In simple words, with this AI enhanced and validation process, the ad delivery data are true and unmanipulated and can be used by advertisers and agencies to make informed decisions about their marketing plan. Practically this means that it is impossible for anyone to "cheat" the terms of the smart contract and falsify the statistics obtained from the database.

  Finally, as mentioned earlier, third-party validators can verify data through the implementation of an open API. In this way any given third-party can act as a validator who records advertising data from an active campaign and cross-checking them according to the rules set by the AI algorithm. In this manner, the transparency and validity of data (i.e., that they originate from human interaction with the video content and not by a machine) is undeniable and cannot be refuted by anyone in the ecosystem.
- **Stage 5 – Completion of campaign (Campaign End):** Upon completion of the campaign (execution of the terms of the smart contract), the display of advertisements by the Ad Server stops. The display data stored in the Blockchain remains unchanged and, at any time, they can be retrieved for analysis or exploitation by the various interested parties.

▪ Challenges and further work

The discussion of blockchain technologies in the digital marketing industry is beginning to heat up. This can be verified by the recent streak of recent published research highlighting the benefits, challenges and obstacles to implementation of this new technology (Malik et al., 2023; Marthews & Tucker, 2023; Peres et al., 2023). During our research with the design and implementation of VidAdChain we have faced some of the challenges already mentioned by the previous researchers but also technical challenges that are, in many respects, the most pressing at this early stage of development.

These technical challenges can be broken into three axes: (i) Data encryption, user privacy concerns and regulatory compliance, and consensus protocols, (ii) Data Storage needs and the scalability of blockchain networks, as video ad serving involves handling a large volume of data and transactions. (iii) Rate of ledger update. Data encryption in Blockchain applications is a critical issue. The higher the encryption level, the higher the cost in computational resources for the writing of new blocks in the blockchain, regardless of the consensus algorithm chosen. Considering that ad transactions could be in the magnitude of thousands per hour, the issue could become a serious barrier to implementation. The PoA consensus offers a cost-effective alternative, although it creates some central points of authority and, correspondingly decreases the data security potential of traditional blockchain technologies. The other two challenges mentioned are both related to the amount of data generated in the digital advertising ecosystem. The architecture of Blockchain demands that all transactions are constantly stored and transferred from one block to the next, thus exponentially increasing the amount of data stored in the ledger. This becomes a significant cost factor if the solution proposed is to be scaled up and achieve commercial implementation. Finally, with the amount of data flooding in even from a single advertising campaign, the issue of how frequent the update of the blockchain should be is another critical issue. Updating the ledger of transactions regularly increases the computational strain but, on the other hand, current digital ad monitoring and delivery services offer an almost live update of ad efficiency data. A blockchain enabled service has to be able to meet the current state-of-the-art features that the market is accustomed to.

Solving these issues is an integral part of our ongoing research. First of all, after the design of the prototype of the service, test campaigns have been performed in order to assess and measure the exact demands on data storage and provide data with the ad fraud limitation that our ad server can produce. Part of the testing will include prioritizing and tracking the most storage demanding parameters of the campaigns. It is likely that we might need a new model to compress campaign data, and/or possibly to use an http layer above the blockchain where all validators' data will be checked and then stored compressed to the blockchain. Moreover, different solutions for storing the verified data will be compared. In the field of encryption, different algorithms will be tested for our solution. Encryption of advertising data does not need the same amount of sophistication as financial transaction data and currently most encryption methodologies originate from fintech blockchain applications.

- **Conclusion**

Our research has demonstrated that integrating blockchain technology into video ad serving can bring numerous benefits to all stakeholders involved. Advertisers can gain increased trust and accountability by verifying ad impressions and ensuring that their content is being served to genuine users. Publishers, on the other hand, can benefit from improved revenue potential through the elimination of ad fraud and enhanced targeting capabilities.

VidAdChain is an innovative research project that is in the process of designing a prototype, blockchain enabled, video advertising management and delivery system. In this stage of the research endeavor, the algorithmic design of the system has progressed, and the main challenges/barriers to implementation have been identified. VidAdChain is currently addressing these challenges and aims to demonstrate by the end of the project's duration a working prototype solution for a blockchain-enabled digital video ad serving and management service.

One of the key findings of our study is that blockchain-based video ad servers can significantly mitigate the issues of ad fraud, such as impression laundering, click fraud, and bot traffic. By recording ad-related data on an immutable ledger, it becomes nearly impossible for malicious actors to manipulate the system, ensuring that advertisers receive accurate and reliable information about the performance of their ads.

Furthermore, the decentralized nature of blockchain technology allows for a more transparent and auditable ad-serving process. Advertisers and publishers can access real-time data and insights, enabling them to make data-driven decisions and optimize their campaigns effectively. Moreover, the use of smart contracts facilitates automated and secure transactions between advertisers and publishers, reducing the need for intermediaries and streamlining the payment process.

In conclusion, our research demonstrates that developing a blockchain video ad server offers a promising solution to address the shortcomings of traditional ad-serving platforms. By leveraging the benefits of blockchain technology, such as decentralization, transparency, and security, we can enhance the integrity and efficiency of video ad serving, benefiting advertisers, publishers, and users alike. Further research and development in this area will be essential to overcome the remaining challenges and fully realize the potential of blockchain technology in the advertising industry.

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