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Designing Distributed Ledger technologies, like Blockchain, for advertising markets

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ABSTRACT

Distributed Ledger Technologies (DLTs), like Blockchain, could help improve brand safety, consumer privacy and transparency in digital advertising. However, paid advertisements transfer attention, money, and data between three parties: advertiser, consumer, and publisher. Therefore advertising-focused DLTs face more complex design considerations than currency-focused DLTs. We describe four key DLT characteristics: structure, participation/governance, transparency, and terms of exchange. We survey current advertising-focused DLTs and find they each serve only two of the three contracting parties in advertising transactions. We make design recommendations for future advertising-focused DLTs, including a goal of serving both consumers and publishers in addition to advertisers. We also recommend governance, transparency and terms-of-trade considerations. Advertising-focused DLTs have significant promise but also significant obstacles, including multi-sided "chicken-and-egg" problems in standards adoption.

1. Introduction

Every paid advertisement connects three transacting parties: an advertiser, a publisher, and a consumer.[1] Publishers harvest consumer attention and data by bundling ads with desired content, and then monetize that attention by selling advertising opportunities to advertisers.

The digital advertising industry has produced numerous valuable innovations and phenomenal growth. Yet despite many successes, there remain some important disconnects between advertisers, publishers and consumers. Among the major issues to be resolved are brand safety, consumer privacy, measurement, market power and transparency (Peres et al. 2022). Several recent articles advocate Blockchain-like technologies as potential solutions to a wide variety of issues in the digital advertising market (Gordon et al., 2021; Pärssinen, Kotila, Rumin, Phansalkar, & Manner, 2018; Ghose, 2018; IAB Tech Lab, 2019; Rejeb et al., 2020; Swartz et al., 2021). Yet, to date, no paper has offered detailed, specific recommendations for designing a digital ledger within the advertising industry context.

The current article has three goals. First, the next section defines distributed ledger technologies (DLT) and identifies four key characteristics in DLT system design. We relate DLT attributes to the multi-sided nature of the advertising market.

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[1] We use the terms "ads," "advertisements" and "advertising" to refer to paid advertisements throughout the article. We distinguish these from "earned media," e.g. mentions of a brand in news reports, and "owned media," e.g. direct promotions, emails or mailers from a brand to consumers. Earned media and owned media are unpaid and subject to different issues than paid ads.

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Next, Section 3 describes the current digital advertising issues that a DLT could help to resolve. It then surveys four extant advertising-focused DLTs and compares structures between them.

Finally, Section 4 connects key advertising issues to key DLT characteristics. We make detailed recommendations for designing future DLTs to serve advertising markets.

To summarize, we argue that an advertising-focused DLT could contribute to advertising contractual standardization, data analysis, supply chain transparency and consumer privacy. It could also ensure human recipients of advertising, increase consumer control over advertising, increase publishers' share of total advertising expenditures, make advertising spending more cost effective, and enable ad effect estimation. To accomplish these goals, a DLT should be designed to serve both consumers and publishers, as well as advertisers. Yet despite these potential benefits, there are significant challenges to DLT system design and adoption. Therefore, the design of any such system must be informed by a deep understanding of the unique economic incentives and market realities of the advertising industry.

2. DLT definition and key properties

We set boundaries by defining DLT and relevant attributes. We refer the interested reader to Peres et al. (2022) and Rauchs et al. (2018) for deeper discussions.

2.1. What is a DLT?

Ledgers were invented thousands of years ago to record details about transactions between parties. A distributed ledger is a network in which multiple nodes enter and store transaction data, including mechanisms to prevent and resolve discrepancies between nodes (Halaburda et al. 2022).

DLT is an umbrella term without a consensus definition, but most people agree that most DLT systems share a particular set of properties. Fundamentally, a distributed ledger is a digital, decentralized transaction database that is managed by a set of nodes without a central server.

Rauchs et al. (2018) sought to reconcile the many conflicting definitions of DLTs. Rauchs et al. (2018) define DLT by saying, "*in essence, a DLT system is a 'consensus machine': a multi-party system in which participants reach agreement over a set of shared data and its validity, in the absence of a central coordinator. What separates DLT systems from traditional distributed databases are features rooted in designs capable of supporting data and maintaining data integrity in an adversarial environment.*" Rauchs et al. (2018) provide further characterizations of DLT systems, in terms of their constituent agent types (administrators, developers, gateways, participants), their constituent components (protocol layer, network layer, data layer), and their constituent properties (recordkeeping authentication algorithms like proof-of-work, proof-of-stake, etc.; ordering; persistence; tamper-resistance; and reconcilability).

A famous example of DLT is the Blockchain, which was included in the original Bitcoin cryptocurrency protocol (Nakamoto, 2018). The primary innovation of Blockchain over earlier DLT systems was to resolve the "double-spending problem" by encoding immutable transaction timestamps within "blocks" and using a peer-to-peer, proof-of-work consensus algorithm to reject any subsequent transaction of the same unit of currency. As Rauchs et al. (2018) noted, "*Blockchain technology is often considered a specific subset of the broader DLT universe that uses a particular data structure of a chain of hash-linked blocks of data.*" In other words, DLT encompasses the original Blockchain, though the term "Blockchain" is also frequently used to refer to a broader class of DLT systems than the original Blockchain implementation.

Blockchain's particular attributes are not necessarily ideal for all DLT applications. For example, proof-of-work consensus consumes substantial energy resources; transaction immutability ensures that erroneous transactions are recorded forever; user pseudonymity may be incompatible with some privacy regulations; and competing approaches are available to achieve system trustworthiness (Kuhn and Yaga 2019). Another common objection to using Blockchain for advertising is that the verification process is too slow to enable real-time bidding (Ghose 2018). Hence, we consider a broader class of DLT systems that includes, but is not limited to, Blockchain.

2.2. DLT properties for design consideration

This subsection defines four key characteristics in DLT system design. Our design recommendations relate back to these later.

(1) **Structure**: Whom does the DLT serve?
New standards in multi-sided platform industries face classic "chicken-and-egg" problems in order to get adoption on multiple sides of the market. Advertisers, publishers and consumers all need to find value in a DLT system, raising significant complications for DLT design.

(2) **Participation & Governance:** Who owns, controls and maintains the *DLT*?
A fully decentralized system (e.g., Bitcoin) allows anyone to introduce and maintain a node and gain trust, for example through proof-of-stake or proof-of-work algorithms. A fully centralized system can license and revoke node memberships and update network protocols more efficiently. In general, more centralized systems may face fewer adversarial

challenges within them and therefore spend fewer resources on achieving consensus between nodes. However, greater centralization also may limit adoption by advertisers, publishers or consumers, and may enable commercial entities to consolidate power and increase fees.

(3) **Transparency:** Who observes what data?
A fully transparent system allows any node to observe the entire ledger, while a fully opaque system limits record access to only the transacting parties. Between those two extremes, a partially transparent system could enable certain parties to access certain transaction attributes. Careful thought needs to be applied as to what information should be disclosed to which parties, as this would influence agents' adoption, usage and trust in the system.

(4) **Terms of Exchange.** Who pays whom, how and for what?
Would an advertising-focused DLT impose a standard business model on ad sales, or would advertisers and publishers choose their preferred business models and payment types? The current advertising market features real-time bids of various types (e.g., cost-*per*-view, cost-*per*-click, cost-*per*-action, fixed fees, etc.) within various types of auctions (first-price, second-price, generalized second price, etc.).

2.3. DLT systems in multi-sided platform industries

Advertising is but one example of a multi-sided platform industry in which canonical DLTs may be extended to serve diverse types of agents. Other examples include credit cards (banks, merchants, consumers), digital or traditional trading marketplaces (manufacturers, sellers, buyers), hospitals (contracting doctors, insurance companies, patients), and software systems like video game consoles or operating systems (application developers, consumers).

Our recommendations follow from our understanding of the multi-sided platforms literature, in which platforms exist to enable productive interactions between agents of different types (e.g., Rochet and Tirole 2003, Anderson and Coate 2005, Armstrong 2006, Wilbur 2008, Ghose and Yang 2009, Belleflamme and Peitz 2022). Platforms typically exhibit "indirect network externalities," in which adoption by agents of one type increases a platform's utility to agents of another type. Indirect network externalities lead to the "chicken-and-egg" problem that a platform must acquire agents of one type in order to become attractive to agents of another type.

Many early DLT systems have been designed to record two-party transactions, without necessarily internalizing the marketplaces in which transactions were arranged. Our focus in designing DLT systems for advertising markets is part of a broader trend in which DLT systems are being adapted to multi-party settings. But, one key differentiating factor between advertising and other multi-sided platform settings is the nature of the indirect network externalities. Most multi-sided platform markets feature positive indirect network externalities on both sides of the market; for example, more seller participation usually makes a marketplace more attractive to buyers, and vice versa. However, in advertising markets, the indirect network externalities are asymmetric: more consumers increase platform utility to advertisers, but more advertisers can decrease platform utility to consumers. Hence, the type of DLT designed for an advertising market may differ fundamentally from a multi-party system designed for a two-sided market context with positive indirect network externalities on both sides.

3. Current advertising issues and DLTs

This section surveys some long-standing problems in digital advertising that might be alleviated by an effective DLT design. It also surveys existing DLTs that have been designed for advertising markets to inform subsequent DLT design recommendations.

3.1. Digital advertising issues that DLT could help to address

Marketers set up programmatic digital advertising campaigns to buy advertising opportunities, using various targeting schemes (e.g., behavioral, contextual, geographic, user/device) to generate bids in real-time auctions and serve customized advertising creatives. This system funds a vibrant open web with extensive free content and has enabled numerous brands to grow and thrive. However, the system also comes with significant challenges:

(1) Many advertisers do not know where their advertisements appear. Brand safety and ad viewability remain important concerns.
(2) 49 % of ad spending goes to intermediaries rather than publishers (ISBA 2020).
(3) A considerable amount of digital ad spend is untraceable and may be susceptible to ad fraud (see, e.g., section 5 in Gordon et al., 2021). Many publishers do not offer advertisers full transparency or accountability. Many online advertisers have trouble estimating advertising effects due to statistical noise, data availability and inconsistency, and other issues (e.g., Johnson 2021).

(4) Many consumers use ad blockers, limiting publishers' ability to monetize free content with advertising, and pushing publishers toward subscription models.[2] Commercial ad blockers also act as gatekeepers, charging around 30 % in exchange for passing through "acceptable" ads (Gordon et al. 2021).

There are two related reasons that advertisers cannot verify advertising services rendered. First, the majority of ads do not immediately lead to conversions, so most advertisers typically cannot verify advertising value independently from publishers. To illustrate this, consider the analysis performed by Gordon et al. (2022) on 1,673 Facebook advertising experiments. The average experiment produced an Average Treatment on the Treated (ATT) effect of less than 1 %. In other words, average conversion rates differed by less than 1 % between users who saw ads and control users who would have seen ads if they had been assigned to treatment instead of control. The large majority of ads do not produce incremental conversions, therefore the advertiser requires some detailed advertising placement data in order to verify advertising services rendered.

Second, most advertisers and their agencies cannot independently verify advertising delivery without conversions due to supply chain opacity. The Incorporated Society of British Advertisers ("ISBA") sought to quantify supply chain opacity on behalf of its members. It asked, "what does my programmatic supply chain look like and how can I assess its value in terms of working media?" ISBA (2020) matched data across 15 major advertisers, 12 advertising agencies, 5 demand-side platforms, 6 supply-side platforms, and 12 major publishers. They were only able to match 31 million (12 %) out of 267 million impressions bought by participating advertisers.

The results showed that, among matched advertising impressions, the average brand advertised on 40,524 distinct websites. Only 51 % of ad spending reached publishers.[3] 15 % of ad spend–31 % of total supply chain costs–was considered untraceable. Earlier advertising audits reached quantitatively similar conclusions, in terms of shares of ad spend taken by intermediaries and considered untraceable (World Federation of Advertisers 2014, K2 Intelligence 2016, Lucidity 2019). ISBA (2020) made two recommendations: (1) standardization is urgently needed across contracts and technologies, to facilitate data sharing and transparency; and (2) industry participants should collaborate to investigate and mitigate unattributable costs. An advertising-focused DLT system could make standardized data available to advertisers by default.

Advertisers have increasingly coordinated their actions in various ways, to their considerable collective benefit. For example, many advertising and media agencies have consolidated within global holding companies, directly lowering procurement costs when an agency represents advertisers that compete in the same advertising auctions (Decarolis and Rovigatti 2021). Advertisers and publishers have also collectively benefitted from new transparency initiatives like ads.txt, ads.cert, sellers.json, openRTB and other protocols developed by the IAB Tech Lab, though adoption and implementation vary across standards. The benefits of further coordinated action could be considerable, so long as it does not violate antitrust provisions.

We are not alone in noting these issues. IAB Tech Lab (2022) says a top priority is "advancing technical standards to combat ad fraud, supply chain transparency, and security." Brave Software (2021), Competition and Markets Authority (2021), Edelson et al. (2021), Gordon et al. (2021) and Permission Token Foundation (2022) offer corroborating descriptions of problems in digital advertising markets and how DLT systems can help to address them.

3.2. Existing Advertising-focused DLTs

We survey-four notable DLTs which currently exist to serve the advertising market, as shown in Table 1. This section reviews how the two most fundamental DLT attributes–structure and participation/governance–manifest in existing advertising DLTs.[4]

One DLT effort, AdLedger, operates as a nonprofit consortium of member firms, including advertising agencies, marketers, publishers and technology firms. The other three systems (AdEx, Brave and Permission.io) operate as for-profit entities. The participation and governance of existing systems vary from closed (Brave and Permission.io) to permission-based (AdLedger) and fully decentralized (AdEx).

AdLedger has proposed a new standard, CryptoRTB, to augment the IAB Tech Lab's existing OpenRTB ad bidding standard. CryptoRTB enables advertising supply chain participants to record immutable identities and other information within a blockchain. It hopes to increase advertising marketplace transparency and reduce supply chain fraud. AdLedger does not operate its own advertising marketplace and its standard does not contain any direct interface with consumers.

AdEx seeks to connect advertisers directly with publishers in an open DLT-based marketplace. AdEx offers full transparency to participating advertisers and publishers. It relies on the consumer's browser memory to store consumer data locally, but does not incentivize consumers to participate in advertising transactions. It does not require any specialized consumer app or browser as all relevant code is served to consumers' browsers by participating publishers (AdEx Networks 2020).

The other two systems, Brave and Permission.io, connect advertisers directly to consumers by using proprietary software to deliver ads directly to consumers' devices and compensating consumers with cryptocurrency. Brave says it shields user

[2] BlockThrough (2021) reports that the ad blocking service Easylist had 257 million desktop users and 586 million mobile users. Its survey of 5,423 US internet users found that 40% of respondents self-reported using ad blockers.

[3] Advertising agencies took 7%, demand-side platforms took 8%, demand-side technology providers took 10%, supply-side platforms took 8%, and supply-side technology providers took 1%.

[4] We do not review transparency or terms of exchange attributes, because we were not able to discover these attributes for all four systems.

Table 1
Brief Summary of Existing Ad DLT Attributes.

	Type	Structure	Participation & Governance
AdLedger.org	Nonprofit consortium of for-profit companies	Serves publishers and advertisers directly, not consumers	Governance: Consortium of member companies Node participation: Permission-based, predetermined nodes (i.e., whitelist)
Ambire AdEx	Commercial service	Serves advertisers and publishers directly, not consumers	Governance: Decentralized system provided by a startup tech provider Node participation: Open nodes without restrictions
Brave	Commercial service	Serves advertisers and consumers directly; publishers can receive consumer donations	Governance: DLT system operated by a single commercial entity Node Participation: Currently closed, with public statements that the DLT could be operated on the decentralized Etherium network in the future (Brave Software 2021)
Permission.io	Commercial service	Serves advertisers and consumers, not publishers	Governance: DLT system operated by a single commercial entity, with a public statement that "*ASK token holders will be able to generate and vote on proposals to govern the underlying protocol.*" (Permission Token Foundation 2022). Node participation: Currently closed.

identities "as a core principle" (Brave Software 2021) and uses a dedicated browser to deliver ads. Brave prices ads as a function of exposure time and viewability within actively-used browser tabs. Brave compensates consumers with cryptocurrency in exchange for attention, and enables consumers to make donations to publishers they like. Brave invites publishers to register in the system to receive rewards, but does not enable publishers to sell their own inventory. Brave says it "*will define further anonymous cost-per-action models as the system develops.*" (Brave Software 2021).

Whereas the Brave DLT seems designed to serve brand advertisers, the Permission.io DLT seems to have performance advertisers in mind. It connects advertisers directly with consumers using a dedicated browser extension (Permission Token Foundation 2022). Permission.io proposes to act as an agent for users, paying them to engage with ads, and enabling them to opt in to sell personal data directly to brands for the purposes of ad targeting and response measurement. Permission.io does not currently include a mechanism to serve publishers or content creators.

In addition to these four existing systems, the IAB Tech Lab, 2019 identified Blockchain as a promising solution to ad tech standardization. However, it did not apparently consider how the three-party nature of advertising transactions might affect Blockchain system design and use. We have not found an update since the 2019 effort, though the Tech Lab's extensive transparency initiatives help to alleviate some supply chain opacity without requiring a distributed ledger.

Another Blockchain initiative has been announced by the Trustworthy Accountability Group (TAG), a consortium of advertising buyers and sellers with a mission to minimize fraudulent traffic. TAG (2022) says that "TAG TrustNET" has received financial support from the UK government and the US-based Association of National Advertisers, but few details are currently available. There are other new commercial initiatives, like Alkimi and Adshares, which were still under development and without a clear structure at the time we wrote this paper.

This industry survey supports the following observations:

(1) Multiple industry players agree that a DLT system could be productive.
(2) There is diversity in how advertising-focused DLTs are designed and what parties they seek to serve.
(3) No existing DLT serves both publishers and consumers in addition to advertisers. They all seek to either mediate advertiser-publisher transactions or advertiser-consumer transactions.

Although the landscape of DLTs in advertising will certainly evolve, we believe this survey could offer durable value by helping to motivate our recommendations below, by bringing further awareness to existing offerings, and by offering a historical snapshot to future entrepreneurs and investors who may consider entering this space.

4. Designing DLT systems to serve advertising markets

This section considers the question of how we might use our understanding of advertising markets to inform the design of an advertising-focused DLT. We make a series of design recommendations for the four key DLT attributes identified earlier.

4.1. Structure

A fundamental issue facing digital advertisers is their frequent inability to verify advertising delivery. One reason for this is that some publishers withhold the advertising delivery data, which can lead to incentive alignment issues. We think the best way to address the issue is to design a DLT that serves consumers as well as advertisers and publishers. In this way, the verification of advertising delivery can be separated from the publisher's economic incentives; ad blocking can be mitigated or monetized; and advertising recipients' humanity can be established.

Recommendation 1. We recommend an advertising-focused DLT be designed to serve the interests of all three transacting parties: advertisers, consumers and publishers.

Without consumer participation, it is difficult for an advertiser to verify whether an ad was shown to a human or machine, or in what context or form the ad was displayed. That may even be true even if publisher incentives were aligned perfectly and if data were fully transparent and available. Yet gaining consumer adoption requires incentivizing consumers, so this is a nontrivial problem to solve, especially when ads are considered as "bads" and blocked by many consumers.

Consumer participation likely requires an application running on the consumer's computer, such as the approach taken by Brave or Permission.io. We presume the most likely approach would be to provide an internet browser or other application (e.g., a smart TV app) in order to receive free or subsidized access to desirable publisher content. For example, suppose the *New York Times* or YouTube offered a 50 % discount or 50 % advertising reduction to consumers who use their preferred application. The browser or app could then be designed to ensure consumer participation in DLT recordkeeping. Of course, the size of the discount has to reflect the marginal advertising revenue of moving a consumer into the DLT system. But the long-term financial gains could be considerable.

Such applications could further facilitate consumer control over advertising exposure. We see several ways to incentivize consumers beyond content access or subsidies: offer improved protections compared to non-DLT alternatives; reduce consumers' ad nuisance, in terms of total advertising load, frequency of exposures, advertising format, or advertising content; and enable consumers to direct payments to their preferred publishers in exchange for appreciated content.

There are various means by which consumer choice of media and advertising could be increased. Consumers could be empowered to restrict entire categories of ads; for example, alcoholics could opt out of advertising for alcohol brands, or gambling addicts could opt out of ads for gambling services. Parents could limit the amount of media exposure their children are enabled to consume. Alternatively, some consumers could be incentivized to willingly opt in to particular ads for products that interest them. Movie fans might prefer to receive new movie ads, or a consumer who is shopping for a new car might willingly self-identify and opt in to increased automotive ads for a period of time.

A desirable DLT system property would be to establish individual consumers' humanity, be robust to adversarial interference in consumer enrollment, or both. We see this idea as similar to "know-your-customer" requirements recently enacted in the US financial services industry. Customer identity is often established by linking an account to a unique valid mobile phone number, bank account and/or physical residence. Consumer identity might alternatively be accomplished by zero-knowledge proofs or other means. If the DLT system cannot verify consumers' humanity, then direct payments to consumers in exchange for usage would likely be infeasible due to the possibility of automated theft. Without establishing customer identity, an open system could be susceptible to unscrupulous actors designing bots to masquerade as consumers and enroll in the system, for the purpose of driving up publisher revenue or advertising prices.

4.2. Participation & governance

There are multiple types of organizations that could try to design and implement a DLT for digital advertising. We see the following as the most likely possibilities:

- A group of marketers could design a DLT to allocate or revise their advertising budgets.
- A group of publishers could design a DLT to sell their advertising space.
- Advertising or media agencies could design a DLT to serve their clients' needs.
- Large digital platforms could introduce a DLT to connect advertisers and publishers with consumers.
- A new commercial intermediary, such as a start-up, could design a DLT for advertising.
- A nonprofit entity representing multiple participants, such as the IAB Tech Lab, could propose a commonly-owned or cooperative DLT.

If an advertising-focused DLT were created and gained sufficiently large publisher inventory, the advertising market could "tip" in a way that the DLT became the most efficient supplier of advertising space. Part of the incentive of creating a DLT may be to influence or capture the 49 % of digital ad spend that currently goes to advertising intermediaries (ISBA 2020). Another part of the incentive of creating a DLT could be the game-theoretic nature of the potential outcome, that is, to not be bound by another entity's rules within a future DLT.

We think some existing nonprofit entities–like the Advertising Research Foundation (ARF), the Association of National Advertisers (ANA), or Digital Content Next (DCN)--may be unlikely to design a DLT due to their organizational designs and limited technical resources. The IAB Tech Lab has not extended its 2019 effort, but in private conversations, IAB Tech Lab staff have indicated that they view their numerous transparency initiatives, like ads.txt, sellers.json, etc., as DLT-like in promoting transparency. However, some of the newer initiatives still have uneven adoption rates and therefore have not achieved the same level of standardization that could theoretically be available from a comprehensive system.

Existing digital platforms likely have the technical expertise required to set up a DLT. Some large ad-exchange platforms have adopted and helped to push new industry standards, like ads.txt, and incumbents have existing advertising revenues at stake. A large incumbent platform might make different advertising DLT design choices than a smaller or newer entrant.

We suspect the best outcome is likely to be one in which a consortium of advertisers and publishers collaboratively own and design a DLT to enable direct payments for advertising services rendered, since advertisers and publishers ultimately

have the most at stake. Yet such an effort may create a classic example of the free riding problem in public goods provision, in which any single agent's return from setting up a collective benefit is much less than the set-up cost, and therefore no agent invests as much as is required to achieve mutually beneficial coordination. Therefore, system designers might anticipate this issue and consider incentive-based remedies, for example by relating ownership of a DLT to the amounts invested to help create it. A related challenge is divisions within advertisers and publishers, such as brand-focused vs performance-focused marketers, or broad-appeal vs niche-appeal publishers.

Conditioning on DLT set-up, we next focus on participation.

Recommendation 2. We recommend that an advertising-focused DLT be open to any identifiable advertiser or consumer who wants to participate; and that some publishers should face some obstacles to participation.

Large and reputable publishers should probably be included by some default rule. However, the open web includes hundreds of thousands of apps and sites that sell advertising. It has been proven in the past that unscrupulous publishers have engaged in a wide variety of fraudulent advertising sales techniques (Gordon et al. 2021, Sadeghpour and Vlajic 2021). DLT systems can prevent some fraudulent practices like double-spending of unique resources, but they cannot always prevent unscrupulous actors from creating entries of transactions that never occurred. Further, a supply-constrained system will feature higher advertising prices and therefore greater incentives for publishers to maintain ethical behavior to remain within the system (Choi and Sayedi 2021).

Most DLT systems designed for cryptocurrency transactions enable pseudonymous currency ownership. However, we see limited reason for an advertising DLT to promise anonymity or even pseudonymity to its advertiser or publisher clients. Therefore we think advertisers and publishers should have to link their ownership to an identifiable human or organization which could be sued or prosecuted in case fraudulent behaviors were detected. We further recommend enabling any advertiser or publisher who is able to use the system, to also be able to operate a node, and to empower the node operators to vote on how the system evolves. It may be interesting to consider allocating voting power nonlinearly according to individual stakes or resources (e.g., quadratic voting, as in Lalley and Weyl, 2018a, 2018b), to reduce the likelihood of system capture by large players.

We also think the DLT system will require multiple checks on client behavior. There would likely need to be systems to ensure local regulatory compliance, as jurisdictions vary in advertising rules related to products (e.g., ads for prescription drugs, addictive substances, firearms or illegal products), content (e.g., false claims, competitor brand use or defamation) and advertising targeting (e..g, senior citizens or other kinds of vulnerable consumers). As another example, payouts to publishers might be delayed by some standard period in order to give advertisers time to detect and raise concerns about fraud.

Finally, we think that consumers should be required to prove their identity, but otherwise face minimal enrollment barriers. We make this recommendation because of expected difficulty of gaining consumer adoption, and the relatively strong efforts we recommend to prevent participation by unethical publishers, which we hope would reduce the incentives to use botnets to imitate human participation or other fraudulent tactics.

We can summarize these recommendations by pointing out that a DLT in a multi-sided platform industry requires a more complicated view of trust than a DLT in a regular market. Publishers are the entities that enable the connections between advertisers and consumers, and therefore play a vital role in maintaining the harmony of the digital advertising ecosystem.

4.3. Transparency

Digital advertisers have long complained about opacity, and transparency is one of the key potential benefits of a DLT. Yet that does not mean that all data need to be observable to all parties, as consumer privacy safeguards are important and required by law in some jurisdictions. We try to strike the appropriate balance in the following recommendation.

Recommendation 3. We recommend the DLT enable all advertisers and publishers to observe all paid advertising transaction metadata, such as context, time and price; and impose some limits on observable consumer information.

We think that limiting advertiser and publisher access to detailed consumer information can help level the playing field between the buying and selling sides of the market. Consumers could be given the option to anonymize or not disclose their own information if they choose to do so. It is possible that reducing access to granular data could worsen advertising targeting and efficacy. However, we think it is an acceptable trade off in some circumstances. Digital data about consumers is often mistaken (Neumann, Tucker and Whitfield 2019) or falsified by consumers. Further, contextual targeting would still be available and can substitute for behavioral targeting information (Goldfarb and Tucker 2011).

We do recommend enabling advertisers and publishers to observe consumer ad engagement data. Examples of such data could include how long the ad was displayed on the consumer's device; whether a session ended during ad exposure; whether the consumer clicked the ad; or consumer feedback about the ad, such as likes, ratings, blocking or reports. This would enable advertisers to use DLT data to estimate aggregate ad effects without observing persistent consumer identifiers, and would enable publishers to evaluate the effects of different ad creatives on their audiences, thereby balancing ad nuisance with revenue goals.[5]

[5] The Private Click Measurement proposal (Wilander 2022) contains some related ideas and provides an example of technical implementation.

4.4. Terms of exchange

We follow the existing advertising marketplace in making the following recommendation.

Recommendation 4. An advertising-focused DLT should enable participating publishers to choose their own business models.

Ideally, a publisher using a DLT to sell ads could specify any contract type and any allocation mechanism. For example, publisher 1 could announce a flat fee for an ad, and then allocate the ad to the first advertiser who agrees to pay the asking price. Publisher 2 could announce a first-price auction for ad display, and then allocate the ad to the highest bidder. Publisher 3 could specify a second-price auction and shade the bids by whether advertisers appear in its whitelist prior to choosing a highest bidder. Publisher 4 could accept bids per click and sell the ad to the highest bidder given a second-price auction mechanism. Publisher 5 might seek to charge advertisers according to how long the ad was displayed on the consumer's screen. There might be combinations of mechanisms or a publisher could offer multiple contract types and let advertisers choose their preferred bid type, including minimum bids, price floors or terms that could be customized to individual advertisers.

Similarly, in such a system, advertisers could have an expanded set of choices regarding how they prefer to pay for ads. For example, a large brand with a high willingness to pay and stringent requirements might run a procurement auction rather than bidding in publishers' sales auctions. It could specify menus of pricing models, bid amounts, publisher whitelists, and advertising inventory characteristics such as times, locations, contextual information or ad engagement requirements.

We see three considerations in designing a fully flexible system:

(1) *Payments*. Advertisers might purchase ads and then subsequently fail to pay for them, so there should be a mutually-trusted standard to ensure advertiser funds availability prior to selling ads.
(2) *Speed*. The publisher's chosen payment model may fail to render quickly enough to take advantage of an advertising opportunity, but we see execution speed as a manageable problem.[6] A high-trust DLT should not require rapid verification of entered transactions in the same way that a low-trust currency marketplace would (Pärssinen et al. 2018). Further, publishers and advertisers can endogenously choose pricing models based partly on speed of execution. If needed, payments can be delayed and transactions can be recorded in batches.
(3) *Interoperability and reselling*. Currently, there are numerous demand-side and supply-side partners that help to enable advertising auctions by providing targeting data, serving advertising content rapidly, re-selling inventory and offering other related services. Careful thought may be required to determine how advertising supply chain partners might interact with the DLT, what services could be rendered and compensated programmatically within the structure of the DLT, how intermediaries would be certified and incentivized, and how private data safeguards could be maintained. Consideration should also be given to whether the DLT can interface by selling inventory to or from the existing digital advertising exchanges–such as those run by Amazon, Facebook, Google, Microsoft, Snap, Tiktok or others–as this may enable increased competition among advertising buyers and sellers and overall market efficiency.

The key point here is to maximize advertiser and publisher participation incentives and flexibility, by enabling them to offer whatever sales possibilities make sense within a given advertising context.

5. Conclusion

Fundamentally, paid advertisements are three-party exchanges of attention, data and money between advertisers, consumers and publishers. There is great potential for an advertising-focused DLT to resolve some difficult issues that have long existed in advertising markets. Yet current offerings only serve advertiser-consumer or advertiser-publisher dyads.

We do not know if it will be feasible to design a DLT that could achieve scale on all three parties of this marketplace. We see the main obstacle as the standard "chicken-and-egg" problem in standards adoption: without publishers on board, no advertiser has an incentive to join and bid; without advertisers on board, no publisher has an incentive to join and sell; without consumers on board, publishers' economic incentives are tied up with data provision and accuracy. Of course, seeking to bring three parties on board at once enriches the standard two-sided chicken-and-egg problem and makes it even more difficult.

The advertising DLT design considerations we have put forth are speculative in nature, given the current state of digital advertising markets and the speed with which technology advances. Still, the digital advertising market is in a state of flux, as numerous structural issues are currently under reconsideration, with new privacy laws, platform regulations, changes to browser cookies, auction mechanisms, advertising intermediaries' market power, and other new rules and lawsuits. So, it is conceivable that the digital advertising marketplace could look different within just a few years. These changes will be further expedited as advertisers and publishers grapple with how to monetize the mobile economy via mobile advertising

[6] Real-time bidding systems conduct advertising auctions in less than 100 ms (Sayedi 2018). Bitcoin technology takes 0.15 *sec* per transaction; Etherium technology takes 0.04 *sec* per transaction. Newer advances include approaches which defer consensus (e.g., Lightning Network) and take less than one nanosecond per transaction (Pärssinen et al. 2018). There are also new hardware designs to enable faster DLT transactions (Bentov et al. 2019).

(Ghose 2017) in the wake of changes brought forth by Apple's ATT policy. We hope this discussion, as well as companion pieces by Malik et al. (2022), Marthews and Tucker (2022), Zhang (2022), Colicev (2022) and Peres et al. (2022), could be helpful to scholars and industry participants as they conceptualize and develop new approaches, and especially if they consider using Blockchain or other distributed ledger technologies.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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