Abstract—The rise of ubiquitous misinformation, disinformation, propaganda and post-truth, often referred to as fake news, raises some concerns over the role of Internet and social media in modern democratic societies. Due to its rapid and widespread diffusion, online fake news have not only an individual or societal cost (e.g., hamper the integrity of elections), but they can lead to significant economic losses (e.g., affect stock market performance) or risks to national security. Blockchain and other Distributed Ledger Technologies (DLTs) guarantee the provenance and traceability of the data by providing a transparent, immutable and verifiable record of transactions while creating a peer-to-peer platform for exchanging, storing and securing information. This article aims to explore the potential of DLTs and blockchain to combat fake news, reviewing initiatives that are currently under development and identifying their main current challenges. Moreover, some recommendations are enumerated to guide future researchers on issues that will have to be tackled to face fake news, as an integral part of strengthening the resilience against cyber-threats of today’s online media.

Index Terms—blockchain; DLT; deep fakes; fake news; data traceability; decentralization; cybersecurity; dApps; information security; reputation; forensics.

I. INTRODUCTION

Gartner predicts that the majority of individuals in developed economies will consume more false than true information by 2022 [1]. Public debate has gone global and it has been completely restructured around its main audience (e.g., actors, gatekeepers and influencers), enabling the formation of groups and the creation of the so-called “global village”. While the usage of online social media to connect with people around the world is rising sharply and the trust in mass media and institutions continues to decline, social media have become an important source and distribution of fake news.

Today, social media platforms miss an adequate regulation and their roles and responsibilities are still not clearly defined. In Europe, a recent legal policy [2] is replacing content-oriented regulation by a content-agnostic approach. Content-oriented regulation forces companies to erase questionable content that obliges them to exercise censorship and likely to sacrifice a large volume of content otherwise protected by the right to freedom of expression. In addition, individuals who upload fake content could get away and upload it again if no adequate rules are implemented in the platform. Nevertheless, the positive impact of these changes remains to be seen. Other social media issues are still open, like the enforcement of adequate data protection rules (e.g., General Data Protection Regulation (GDPR)) along with the market concentration in just a few social media companies worldwide.

Fake news are generally understood as false or misleading information produced and disseminated to intentionally cause public harm (e.g., post-truth, populism) or looking for obtaining a profit (e.g., clickbaits, cloaking, ad farms). Fake news originate either from governments or non-state actors publishing content without economic or educational entrance barriers. This horizontal and decentralized communications cannot be controlled with the same tools as the traditional centralized mass media. This lack of supervision has allowed for rapid innovations aligned with business interests (e.g., social engineering). Moreover, traditional mass media are not out of the discussion, since the veracity of their information appears to be sometimes negotiable for the sake of turnover growth, as the competition is increasingly tough.

Recently, the significance of the situation has induced several research projects as well as legislative initiatives [3]. In the current online environment, abuse of personal data (e.g., monetization) represents one of the biggest threats, especially with regards to emerging technologies and to the lobbying power of the interested stakeholders [4].

Researchers argue that, while the ubiquitous content itself can be hardly controlled, the traceability of the data, the architecture of the communications and the transactions, can be supervised. Nevertheless, the problems involved in developing effective ways to identify, test, transmit and audit information are still open. Today, Distributed Ledger Technologies (DLTs) and specifically blockchain, pose new challenges but also opportunities for policymaking as a potential technology that can help to combat the challenge of fake news. These technologies enable privacy, security and trust in a peer-to-peer (P2P) network in a decentralized fashion without the presence of a central managing authority.

There are only a few articles of the literature that use blockchain to combat fake news and they are mostly focused on tracing the source of the news. But, to the knowledge of the authors, this is the first article proposing a holistic approach to combat fake news through DLTs. Thus, it is provided a comprehensive overview of the phenomenon and its prevalence, the applicability of DLTs to tackle fake news and the main challenges they pose. The aim of this paper is to foresee the potential contribution of DLT for revolutionizing
the media industry and face today challenges.

The rest of this paper is organized as follows. Section II reviews the state-of-the-art of fake news and related technologies. Section III proposes different applications of DLT to combat fake news. In Section IV the main challenges of the application of DLT to tackle fake news are analyzed and some recommendations are proposed with the aim of guiding future researchers on some of the limitations to be confronted. Finally, Section IV is devoted to conclusions.

II. STATE-OF-THE-ART

A. Main characteristics of fake news

A fake new is characterized by the following main elements (which are extended in Table I):

- Its information/content is designed to be wholly or partly false, manipulated or misleading, or it uses unethical persuasion techniques (e.g., propaganda or ideology-driven content).
- It is focused on generating insecurity, hostility or polarization, or attempt to disrupt democracy, in particular democratic processes like elections and referendums, fundamental rights or the rule of law.
- It covers matters of public interest (e.g., politics, health, environment).
- Its information is disseminated strategically through automated and aggressive techniques (e.g., campaign-like manners, fake accounts), such as social bots, micro-targeting or paid human trolls that boost public visibility.
- It has characteristics that enable rapid and widespread diffusion. Fake news are likely to spread faster, deeper and more broadly than the truth [5].

B. Prevalence and impact of fake news

Although the relationship between the cause and effect of fake news still needs to be scientifically proven, in at least a few cases (e.g., the Brexit campaign), they appear to have made a significant impact on public behaviour. An example is the so-called misinfodemics, where health misinformation (e.g., the effect of vaccines) is enabling the spread of diseases. Fake news impact two main areas:

- Privacy and data protection. Services offered by platform providers are increasingly driven by the big data monetization. For example, biometrics or voice and facial recognition appear to further increase the vulnerability of data privacy having, in some cases, personal data involuntarily exposed (e.g., psychological traits).
- Individual freedom of expression and right to receive and have access to a trustworthy information.

C. The role of emerging technologies and deep fakes

To forge information has never been easier thanks to a range of free content-generation software. Furthermore, with the rise of emerging technologies like Internet of Things (IoT) people will be more exposed to being monitored and tracked to collect big data, and the capacity to imitate reality through Augmented Reality (AR) and Virtual Reality (VR) has already been misused [6], since immersive experiences are less subject to rational thinking and they amplify the effects of potential manipulations.

In addition, Natural Language Processing (NLP) and AI are expected to drive the future “counterfeit reality”, where distinguishing between original and manipulated content will become close to impossible for people and progressively difficult for machines [7]. For instance, Deep Learning (DL), a subfield of Machine Learning (ML), is being increasingly used to create models such as Generative Adversarial Networks (GANs) that enable realistic manipulations of image and video that are recognizable by both human and machines (i.e., they create “deep fakes”).

The emergence of deep fakes will exacerbate significantly the impact of fake news. Individuals, businesses and society as a whole may face novel forms of exploitation, intimidation, or even personal sabotage, as well as additional risks for democracy and national security.

| Type of content | Platforms | Originators | Targets | Objectives | Tools | Solutions |
|-----------------|-----------|-------------|---------|------------|-------|-----------|
| • Text          | • Traditional mass media | • Governments | • Elections | • Misinformation | Ensuring transparency and data protection |
| • Image         | • Fake news sites | • Political parties | • Referendums | • Disinformation | Independent-fact checking |
| • Video         | • Social media (Twitter, Facebook, Instagram, Reddit) | • Military | • Anti-migrant campaigns | • Hexes | Quality journalism and media literacy |
| • Audio         | • Messaging apps (Whatsapp, WeChat) | • Economic elites | • Financial information (e.g., stock market) | • Mal-information | Data trustworthiness |
|                 | • Google, YouTube | • For-profit organizations, business competitors | • National security | • Propaganda | Clickbait, cloaking and ad farms detection |
|                 | • Wikipedia | • Advertisers | • Science and technology | • E-mail hacking | Propaganda detection |
|                 | • News media | • Organized crime (e.g., mafias) | • Entertainment | • Releasing confidential information | Network-based spread analysis |
|                 | • Urban legends | • Natural disasters | • Natural disasters | • Hate speech | Impact measurements on citizen beliefs and behavior |
|                 | • Urban legends | • National security | • Urban legends | • Spammer, bot and troll networks | Debunking myths |
|                 | • National security | • Political parties | • Urban legends | • Misinformation | Regulatory actions, policy initiatives |
|                 | • Political parties | • Military | • Urban legends | • Disinformation | Ransomware protection |

TABLE I

MAIN FAKE NEWS FEATURES: CONTENT, PLATFORM, ORIGINATORS, TARGET EVENTS, OBJECTIVES, TOOLS AND SOLUTIONS.
Several approaches have been described in the literature that make use of modern tools and techniques, and that combine technologies to tackle the problem of fake news (e.g., network analysis, crowd-sourcing algorithms). On the one hand emerging technologies will make fake news significantly more successful, both faster and with practically no risk, but, on the other hand, the same technologies can help to tackle them (e.g., smart filtering [8], characterization and detection [9]) and leave traces that enable further investigation of malicious actions.

D. The role of new media

Users have been misled into believing that the information they consume is spontaneous, citizen-generated, objective and universally encountered by other users, while, in fact, it may have been provided strategically and micro-targeted. Social media platforms do not generate content themselves, but they transmit, organize and amplify it. Their terms of service collect big data about their users, and make them available for commercial and political actors, to enable targeted advertising, massive profiling, advanced demographic analytics and the automation of content. For instance, the lack of transparency makes it complicated to trace the original advertisers (they may intentionally hide their identity or use intermediaries) and obtain digital evidence to reinforce liability.

E. DLTs and blockchain capabilities

Distributed Ledger Technologies like Tangle or blockchain are able to provide seamless authentication, efficient and secure data storage, processing and sharing, robustness against attacks, scalability, transparency and accountability. Such features (illustrated in Figure 1), together with the utilization of smart contracts enabled by oracles, can play an effective role in combating fake news considering that transactions cannot be tampered once they have been distributed, accepted and validated by a network consensus [10] and stored in blocks. Moreover, transactions are easily auditable by all the involved stakeholders. Although a description on the inner workings of DLT and blockchain is out of the scope of this article, the interested reader can find detailed information on how to design a blockchain according to the business needs and deployment environment in [11], [12].

III. LEVERAGING DLTs TO COMBAT FAKE NEWS

There are just a few studies that analyze the use of DLT for fake news identification, prevention and detection. This section reviews the most relevant applications, which are summarized in Figure 2.

a) Content moderation: conventional content moderation processes (e.g., flagging, notice and take down) assume the presence of a centralized regulator and the technical possibility to remove the content immediately. This is not necessarily true in DLTs, especially in the case of permissionless networks, where anyone is allowed to participate or become a transaction validator, and there is no central authority. Therefore, additional research will be needed in this field.

b) An open protocol for tracking news credibility: Qayyum et al. [13] introduced the concept of Proof-of-Truthfulness (PoT), where any node in the network can verify whether a content is or not part of a blockchain. Content is stored in a Merkle tree, a binary tree built using hash pointers in which nodes at \( n - 1 \) level contain the hash pointers to the content stored at \( n \) level. Given a specific content, its trustworthiness could be verified in \( O(\log(n)) \) by searching throughout a single tree branch from the content to the root (level 0).

c) Incentivized discovery of truth and quality fact-checking: the Latvian 4Facts.org platform [14] is an example of scalable blockchain-based solution for fact-checking. Reliable fact-checkers are identified (since they are interested in validating content) so they can get financial rewards (e.g., tokens), as well as increase their reputation for high-quality work. The amount of rewards increases as the fact-checker improves his/her reputation. In the proposed system, content creators will be also interested in submitting their content for validation in order to build their reputation.

d) Creation of social media platforms that use digital identities: the Solid (Social Linked Data) project [15] led by Tim Berners-Lee together with the MIT is a proposed set of
tools for building social decentralized applications (dApps) based on Linked Data principles, resulting in improved privacy as well as true data ownership, access control and storage location.

Another example is the Content Blockchain Project (iRights.Lab, Germany) [16], an open and decentralized blockchain ecosystem for the distribution of media content operated and owned by the industry itself. As a main element of the project, they developed a standardized International Standard Content Code (ISCC), comparable with established identifiers, such as International Standard Book Number (ISBN) or International Standard Serial Number (ISSN), but with enhanced functionality in order to create a user-friendly application that generates ISCCs without any cost. The project is also working in the simplification of the licensing of digital content, so that it can be granted in a simpler and quicker way.

e) Reputation systems: computing a reputation score can be used for quantifying the credibility of a publisher and warn readers when the content shows traits that may indicate biases. In [13], it is proposed a dynamic reputation set: an initial zero score is assigned to each non-verified media and the score evolves as the entity shares trustworthy verified news. If a minimum reputation score is not achieved within a specified time slot, its identity will be revoked. Registered consumers provide feedback through the platform or score the credibility of the content, like in the case of BitPress [17]. Nevertheless, the problem of subjectivity, bias and the risk of malicious actors have to be further studied.

f) Authenticity of digital media: automatic management of non-tampered content and multi-node content verification can help to overcome the problem of verifying big data news streams. DLTs inherently guarantee data integrity once transactions are stored. This feature makes DLT an essential infrastructure for notarization services [18]. Nevertheless, a central problem is how to ensure data are not forged before they are inserted into a block. Service providers can take a fundamental role to provide a tamper-proofed way to notarize content (e.g., by generating a digital signature) using a Public Key Infrastructure (PKI).

g) Provenance and authorship: the use of DLT technology would also allow for making content forgery almost impossible by demonstrating its origin and, in case of detecting a fake, it would make the source accountable. Provenance is useful for multimedia content that can be forged through deep fakes. Huckle et al. [19] proposed an Ethereum framework with standardized metadata for the verification of the authenticity and the provenance of digital media. Such a prototype uses Interplanetary File System (IPFS) [20], a P2P content-addressed file system. Nevertheless, the ability of the proposed system to find fake resources is somewhat limited (i.e., it is not able to prove the authenticity of a story as a whole).

h) Community-driven dApps: crowdfunding approaches can use tokens to incentivize the discovery of truth. In DLT-based social networks, users can exchange tokens or coins through the same social network in a straightforward way. For instance, users can make a business without third-party intermediaries through cryptographically signed smart contracts with secure and fast P2P transactions.

i) Additional platform-based services: Online platforms (e.g., Mozilla, Facebook, Twitter) and trade associations (e.g., EACA, IAB Europe and WFA) have made some progress in their commitment to tackle fake news [21]. For instance, Google has announced the Google News Initiative to support the news industry in quality journalism.

j) Forensics: it is challenging to make sure that devices, content and intellectual property are legitimately used with authorization and to prove forensically with a certain degree of confidence when otherwise. Once security is compromised, there is an intellectual right infringement, or a counterfeit, forensics recreate what has happened to answer what, when, who, where, and how. DLT-based notary services offer unarguable digital evidence because the integrity of the content has been cryptographically guaranteed.

k) Data traceability: Shang et al. [22] trace the source of news by keeping a ledger of timestamps and the connections between the different blocks. The procedure proposed is as follows. First, when media are writing news, the related content, category and other information are uploaded to the blockchain. Then, in the process of communicating the news, it is recorded the release date, the hash value and the timestamp of the pre-block so that the chain structure can be formed. Third, when readers consume news, they can trace the source through the chain structure of the blockchain and the stored information. Although this scheme seems promising, the authors point out that the construction of the whole traceability system needs to be further explored.

l) Usage of smart contracts: a smart contract can add functionality to a DLT as it is a computer program that is stored in the distributed database. Smart contracts allow for the addition of validations, constraints, and business logic to transactions in a form of an agreement between parties. For example, a smart contract can be used to store relevant information such as publisher identity, status, reputation score, public key, timestamp, and then broadcast the content to the P2P network.

Smart contracts can also be used to register, update and revoke the identities of different organizations (e.g., publishers), as it is indicated in [13] (they may also add their status and reputation score):

- Registration: the DLT-based system has a mapping of the active public keys of different media organizations to verify their identities. In case there is not such key for a certain organization, the platform could collect the information through third-party Application Programming Interfaces (APIs). When a media organization signs up, the system checks its identity by asking it to sign a message with its existing public key. When the process is successful, the entity receives a verified status; otherwise, it remains as a non-verified organization. The system assigns a pair of public and private keys to the enrolled entity, which will be used in a digital signature scheme.
• Update identity: an enrolled entity can modify its identity or obtain multiple identities in the form of a pair of public and private keys. Publishers can be required to prove its previous identity (i.e., the public key previously registered) through a smart contract.

• Revoke identity: the revocation manages the automatic termination of existing organizations either by request or if the DLT-based system has identified an infringement.

IV. CHALLENGES AND RECOMMENDATIONS

The current efforts of the research community are mostly focused on one type of fake news (i.e., verifiable false content), while other bad practices are barely studied.

Current proposals use mainly hashing nevertheless, these approaches cannot always guarantee a correct functioning. Hashing is sensitive to noise and when there is a change of a character, a pixel or a bit in a certain content, it can result in a different hash. While any minimal change in two resources will generate vastly different cryptographic hashes, the use of perceptual hashes produces comparable results if the resources are similar. Hence, perceptual hashing is already used to detect copyright infringement as well as in digital forensics. Another alternative to overcome this problem is the usage of a semantic similarity index of a content published by different sources. This index can be measured by ML methods (e.g., word2vec) and it can be used to assess the integrity by checking it on the DLT (i.e., if it was published or not by a verified entity).

The DLT system alone is not able to fully evaluate the authenticity of an input content. Consequently, it is essential to develop a system that is resilient to data falsification attacks, which inserts forged data into the DLT to deceive others. To face this issue, it is recommended to include contextual knowledge to corroborate the integrity of the news. Further research may include the use of DLT together with AI and NLP methods, to develop deep insights about similarities and to quantify trustworthiness.

Strengthen cybersecurity and preserving privacy and security of content shared on social media is also a key issue, since they may be used to train an ML model to create fake content. DLT-based solutions can cryptographically store the content in such a way that every transaction and interaction on the DLT (i.e., if it was published or not by a verified entity).

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