Semantic Web with Block Chain Technology Parsing New Trends to Extract Novel Scientific Demands

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Abstract. Blockchain technology has become widely used across various sectors such as industry, research, and academia. Over the past decade, numerous complex problems specific to different domains have been successfully addressed with respect to blockchain. As a result, researchers have shown interest in integrating blockchain with other well-established technologies, such as the Semantic Web. However, there are no clear depictions among the researchers in contrasting the various use cases in which Semantic Web and blockchain can be merged and no fore castings related to the potential benefits for both technologies. This paper aims to provide a comprehensive understanding of the mutually beneficial relationship that these technologies can achieve when integrated, and it also highlights the different scenarios noticed throughout the literature for generating a new a wave of scientific approach for combining the Semantic Web and blockchain. The objective of this paper is to review the innovative approach of merging the Block chain with semantic web to solve many problems in a simpler way.

Keywords: Blockchain technology · Semantic Web · Resource Description Framework (RDF)

1 Introduction

Over the past decade, blockchain technology has become ubiquitous in various sectors, including finance, security, IoT, and public services [1]. Researchers have taken an interest in exploring the challenges and problems associated with the use of blockchain technology in these domains [2, 3]. One area of particular interest to researchers has been the combination of blockchain technology with the Semantic Web [4, 5]. This interest

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stems from the potential for a symbiotic relationship that could enhance both technologies [6]. In the existing body of literature, the primary emphasis lies on applications that utilize both blockchain and Semantic Web technologies. However, there is only one article, authored by English et al. [7], that specifically examines the advantages of integrating these technologies. However, their work provides an overview of the benefits of the combination, rather than an in-depth analysis.

This paper aims to build upon the research conducted by English et al. [7]. by offering an expansion on their findings a deeper examination of the benefits that blockchain and the Semantic Web can offer to each other. As experts in the field, we provide a comprehensive examination of the various strategies and methods for integrating these technologies. Our analysis includes a thorough evaluation of the merits and drawbacks associated with each approach. The organization of the paper entails with various sections and each section describes essential information pertaining to semantic and block chain technologies. The Sect. 2 evolves with the basic concepts of both the semantic and block chain. Section 3 highlights the advantages of merging these two technologies. Moving on to Sect. 4, we delve into various scenarios where the combination can be beneficial. Lastly, in Sect. 5, we present a summary of our findings and conclusions.

2 Preliminaries

In this section, the preliminary objective is to offer a comprehensive understanding of the fundamental principles and distinguishing features of both blockchain technology and the Semantic Web. The paper's objective is to explore the fundamentals and a promotion in both the techies, which will serve as a foundation for discussing the benefits and scenarios of combining them while exploring the pros. The challenging task in the current scenario is collection of huge voluminous data day by day. This data can be restructured and organized in an efficient means through this approach.

2.1 Blockchain

Definition 1 (Blockchain). The blockchain is a decentralized, shared database that contains a list of blocks. In the realm of data structures, each block is equipped with essential metadata, various hash functions used for all previous and present blocks of data. The content of a block can be expressed in various formats, but once information is added to the chain, it becomes immutable and cannot be modified by anyone.

Definition 2 (Block). A block is the basic storage unit of the blockchain. It contains metadata and content, in a professional manner, the metadata contains the hash codes derived from the preceding block and the present hash [8]. The content of a block is limited in size, which varies depending on the implementation, and the metadata may also vary based on the implementation.

It is important to mention that various versions of blockchain, like Bitcoin or Ethereum, may exhibit certain distinctions, but they all adhere to the fundamental principle of being a decentralized database validated by peers without the involvement of a third party [9]. The process of adding a new block to the chain follows a specific protocol, wherein the newly developed blocks are generated using the hash functions from the previously generated blocks. All the block in the chain are authorized to be communicated among its peers. The block is included in the chain once it has been validated by all other peers [2, 10].

There are three types of blockchains depending on the access rights and privileges of the peers: public, consortium, and private. In a public blockchain, anyone can access the chain and write new blocks, even anonymously. In a consortium blockchain, access is limited to invited peers, but once invited, they can implement writing a code to generate new blocks in the form of a continuous chain and permissions are granted to only invited peers to access the chain, and they need additional permissions to write in it. Despite being more secure than other data stores, blockchain technology suffers from a limitation of scalability, and blocks of data with larger volume of data require more storage space and slow down the propagation of the block to other peers in the network.

2.2 The Semantic Web

The Semantic Web is a novel approach to its kind for all the documents available in the web, and it is equipped with a suite of custom-made technologies [11]. From the extensive semantic web technologies collection, we will highlight the most important ones and their core functions.

Definition 3 (RDF). The Resource Description Framework (RDF) is a standard formal language promoted by the W3C that allows for the description of data in any format [12, 13]. This data is expressed in the form of triplets, consisting of a subject, predicate, and object, where the first and second elements are represented by URIs, and the third element can either be a URI that relates to a literal or a subject in the RDF data representation. The content of the RDF is duly represented in the form of a graph for easy analysis and understanding and the same can be utilized for mapping references.

Definition 4 (Virtual RDF). Virtual RDF refers to RDF data that is generated on the fly, either by reading stored RDF data or by transforming heterogeneous data sources into RDF format using user-defined specifications. This allows for the dynamic creation of RDF data without the need for storing it in a file or a triple store [14].

Definition 5 (Linked Data). The Linked Data allows to connect data across multiple sources, by using common identifiers and linking the data to other related pieces of information. This creates a web of interlinked data that can be easily navigated and understood, making it easier for people and machines to find and reuse the data. The term “Linked Data” refers to RDF data that adheres to the guidelines established by Tim Berners-Lee [15]. These guidelines consist of a set of requirements for data quality, including:

1. URI are recognized as and then used as an identifier for the available resources.
2. Implementing HTTP URIs that are user-friendly and easily accessible.
3. Incorporating standardized methods like RDF and SPARQL to provide valuable information when a URI is accessed.

4. Including hyperlinks to other URIs to enhance the process of exploration and discovery.

The principles of Linked Data require that resources are identified using URIs. The resources are also further identified by means of DNS (Domain Name Space) which is on the threshold for publishing data. As resources are dependent on DNS, if there is a change in the DNS, the resources will no longer be accessible through their original URIs. Despite the decentralized storage of the data, when consuming Linked Data, it appears as a unified dataset due to the connections among the existing datasets based on the availability in the repositories.

Definition 6 The World Wide Web Consortium (W3C). Has introduced two official languages, RDFs and OWL, for data modelling [16, 17]. These languages are utilized for creating ontologies, which are formal models that enable reasoning over the described data. This implies that ontologies can ensure the coherence of data and generate new data through logical mechanisms, even if it is not explicitly defined or stored. The literature offers a range of standard, domain-specific ontologies suitable for different applications [18].

Definition 7 (Ontology Mappings). Ontology mappings are a key aspect of the linked data approach. They provide a mechanism for connecting different ontologies, allowing for the seamless integration of data from various datasets. With mappings in place, though a non-recognized ontology is used for modelling, automatic detection is done for that ontology depending upon the mappings. This enables the storage and consumption of data as a unified whole, enhancing the efficiency and flexibility of the linked data approach.

Definition 8 (SPARQL). SPARQL is a formal language promoted by the W3C for querying data expressed in RDF that follows an ontology [19, 20]. Utilizing an RDF engine capable of comprehending vast amounts of data, SPARQL empowers users to effortlessly query and retrieve information from either a single dataset or multiple datasets concurrently via SPARQL federation facilitating required extensions for all necessary queries [21].

Definition 9 (Data Shapes). RDF data has evolved with certain limitations and the certainty and compliance is supported by the W3C. W3C has introduced the concept of Shapes which compasses the certainty of language called Constraint Language [22], also known as data shapes Language. This language enables the definition of various constraints, ranging from the necessary data structure to the formatting of literals using regular expressions. Additionally, data shapes facilitate the creation of virtual RDF through SPARQL definitions.

3 Benefits

English et al. in their work [7] highlighted a key advantage of using Semantic Web in blockchain, which is the ability to model block meta-data using ontologies, allowing for querying using SPARQL. However, this approach has a drawback as it is limited for querying all the necessary contents of the respective blocks, because the data is not stored in designated RDF format. Simultaneously, Semantic Web can also benefit from blockchain technology in terms of resource identification. Normally, IRIs in Semantic Web rely on the DNS system. In the blockchain technology, hashing is a common methodology to identify block resources, thus decentralizing the domain name system. The semantic web ensures the data retrieval in an efficient manner. The block chain technology enables to interconnect the required data needed by the user. Both these techies are a must need for the data engineers to solve complex issues.

After conducting a thorough analysis survey for both the technologies, a report comprising of comprehensive list of benefits that the blockchain can reap from Semantic Web technologies is generated. The following points highlights some of these benefits:

1. **Versatile Language:** The RDF standard allows for flexibility in data representation, as it is not limited to a specific format. TURTLE, RDF/XML and JSON-LD are some the universal formats prescribed for RDF to represent the information. This can be one among the proven statements to trust that the RDF is versatile. The blockchain shall utilize the services offered by RDF like writing contents with respect to blocks, preparing necessary prerequisites for establishing the required formats that suits a respective domain.
2. **Well-established Data Modelling Standards:** The W3C standards, such as RDF, SPARQL, RDFs, and OWL, are highly regarded Semantic Web technologies. This implies that there is a global agreement on their reliability and trustworthiness. Additionally, there is a vast collection of standard ontologies available for use, which simplifies the task of data modelling for a given problem by providing ready-to-use solutions for a range of domains.
3. **Data Connectivity:** RDF's advantage is its ability to connect to data from other datasets by utilizing links, resulting in a comprehensive view of the information despite its decentralized storage across the web. The challenge of linking data is well acknowledged and extensively tackled in the Semantic Web community by all the researchers [23]. The fundamental property of the block chain is to link the blocks of data with external datasets or even with other blocks within the same or different chains, enhancing the overall interconnectedness of the data stored in the blockchain. This can be one among the most important advantageous features of Blockchain.
4. **Multiple Data Representations:** The main functionality of the Ontologies to facilitate mapping features to connect to the classes of other ontologies with all the properties and features. This feature allows a blockchain to translate the data described using one ontology to the representation of another ontology through these mappings. This is especially useful when data needs to be modelled differently depending on the consumer. By utilizing ontologies with mappings, the blockchain can ensure that the same data can be viewed in various forms to accommodate different stakeholders.

5. **Searching within the Blockchain**: SPARQL is one among the popular query language used for executing users queries in RDF. The same can also be used when integrated with block chain. Block chain adopts use of the ontologies in the RDF at semantic web to mention various elements, contents and available sources of meta data. The service acts as an intermediary, bridging the gap between the raw data stored within the blockchain and the querying mechanism.
6. **The process of validating data and meta-data in blockchain** can be improved by incorporating ontologies and RDF. By using "shapes," blockchain uses prediction analysis to detect the error codes in the existing models as well as in the document sets of RDF to rectify the prevailing bugs and forecast the RDF's content for redundancy. This validation technique ensures the accuracy and integrity of the data stored within the blockchain, enhancing its reliability and trustworthiness. Consequently, users can derive more value and utility from the blockchain.
7. **Ensuring Blockchain Consistency:** Reasoning engines are one among the prime causes in the semantic web structures for validating the integrity and coherence of data. In this particular situation, the blockchain would rely to seek the support of a third-party agent to perform the logical processing and to communicate its metadata with a unique structure called ontology. This service would ensure that the data within the blockchain adheres to a set of logical rules and regulations, making it more consistent and trustworthy. By incorporating this validation step, the blockchain can provide its users with a higher level of confidence in the accuracy and reliability of the data stored within it.
8. **Virtual RDF:** There are several ways to generate virtual RDF, including the use of reasoning engines that infer new data, inferring virtual RDF using data shapes, and using graph embeddings that analyse the existing data and recreate newer outputs [24] through machine learning practices. These approaches provide a flexible and dynamic way to generate and access RDF data, making it easier to adapt to changing needs and requirements.
9. **Services offered by Virtual RDF:** The Semantic Web converts data from different sources into RDF on the fly, based on specific specifications [13, 14]. The conversion takes place with the help of convertible engines on board during RDF data manipulation. Blockchains can also take advantage of these virtual RDF services by storing information in formats other than RDF and utilizing external services to create their RDF content instantly. This allows the blockchain to store data in a variety of formats, while still providing a unified and standardized representation of the data in RDF, which can be easily consumed and processed by different systems. The use of virtual RDF services can provide more flexibility and interoperability in the data management of blockchains [24].
10. **Interoperability:** Common Ontologies are always subtle to deal both semantic and blockchain. Hence, it falls in the category of inoperable circumstances. Modelling of data and meta data is quiet inoperable. The blockchain becomes interoperable by utilising Semantic Web technologies and employing common ontologies to model both metadata and content. An information system is said to be interoperable if it can easily pass correspondence to their corresponding interoperable systems. Additionally, the data of interoperable systems can be automatically found and accessed by third-party systems. This allows for greater data integration and sharing between

different systems, improving overall data management and exchange. Interoperability also enhances the blockchain's compatibility with other technologies, making it easier to integrate into existing systems and workflows.

The Semantic Web may experience the following advantages by utilizing blockchain technology:

1. Decentralization and security: Blockchain provide a decentralized and secure platform to store data, which can enhance
2. the reliability and trustworthiness of the data in the Semantic Web.
3. Immutable record: Blockchain allows for the creation of an immutable record of data transactions, making it easier to maintain the integrity of data in the Semantic Web.
4. Transparency and accountability: Blockchain allows for the creation of a transparent and accountable record of data transactions, making it easier to track the usage and history of data in the Semantic Web [25].
5. Autonomy and Interoperability: Blockchain enables autonomous systems to securely exchange data with each other, improving interoperability and data integration in the Semantic Web.
6. Cost-effectiveness: By leveraging the decentralized nature of blockchain, the cost of maintaining and exchanging data in the Semantic Web can be reduced, as there is no need for intermediaries.
7. Better Data Management: Blockchain enables the creation of a unified and consistent data management system that spans across different systems, improving the overall data management in the Semantic Web.

4 Blockchain and Semantic Web Comparisons

The Semantic Web refers to a collection of technologies that concentrate on describing, modelling, and connecting data. On the other hand, the blockchain is a technology designed for storing and sharing data among a network of peers who verify its contents without relying on third-party involvement. The combination of these two technologies offers benefits for both. The blockchain have advantages in the form of storing large blocks of data using semantic technologies while semantic web on the other hand is benefited from the decentralization and immutability of data offered by the blockchain. Currently, there is only one known article that delves into the potential combination of these technologies, as presented by Ugarte [26], who described three scenarios. Upon conducting a more in-depth examination of the latest advancements, we have discovered six specific situations that will be elaborated on in the subsequent sections.

4.1 Semantic Metadata on the Blockchain

This integration state involves the use of an ontology to express the meta-data of a blockchain. The available content of the block is stored and represented in the form a non-RDF compliant format. The ontologies on the other hand depicted the usage [27] and none of them have achieved the prominent status yet. The first step towards combining the technologies of the in this state is shown in Fig. 1, describes the Semantic Web and Blockchain. Figure 1.

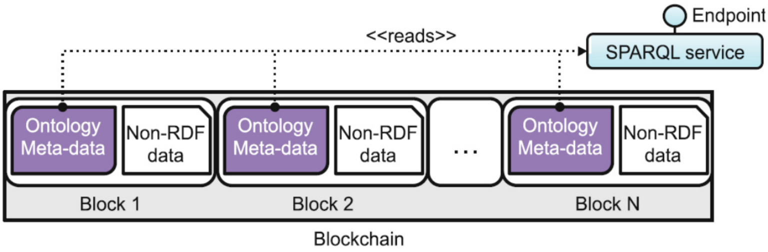

Fig. 1. Meta data referencing Ontology with Blockchain

In this first scenario, the advantage is that users can search for blocks based on their metadata, as long as an external service is available to read the blockchain and process SPARQL queries. This allows for searches of all blocks with a hash matching a specific pattern. However, one limitation is that Semantic Web technologies are only used to express the metadata of the blocks, limiting the potential benefits to just executing SPARQL queries on the metadata.

4.2 RDF-Based Blockchain Content

The integration of Semantic Web and blockchain in this demonstration involves utilizing RDF to store data in blocks, as depicted in Fig. 2. This approach complements the previous scenario, and any RDF-supported format, such as JSON-LD or XML/RDF, can be used to express the block's content.

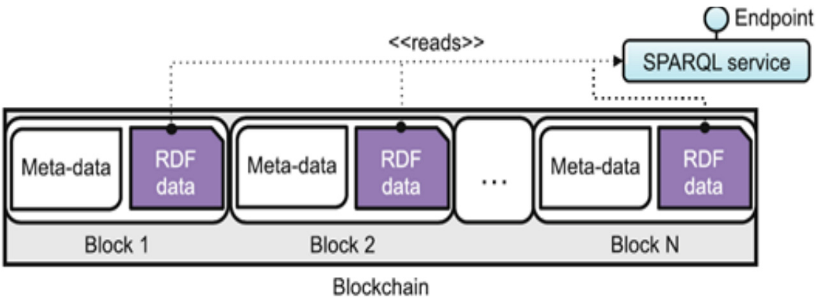

Fig. 2. Data representation in RDF format over a Blockchain

If There is a third-party service capable of processing SPARQL queries and reading the blockchain, this scenario offers many advantages. Practitioners can utilize SPARQL queries to search through the content and metadata of the blocks, which were described using an ontology. This enables the blockchain to gain all the benefits on our list.

Storing links to external data sources or ontologies in the chain is necessary. However, this scenario's primary disadvantage has not been thoroughly studied. The designated RDF formats available so far require a large number of characters and are verbose and the limitation is that the data stored in the form of blocks is restricted to some limited quantity. Therefore, RDF may require numerous blocks to store and define the information as non-RDF formats, which could decrease blockchain efficiency. To our knowledge, no research has examined the feasibility or efficiency of this scenario.

4.3 Virtual RDF and Blockchain

The virtualization services utilize the blockchain as a source of data and create RDF, as illustrated in Fig. 3. SPARQL is a query language specifically used on the data sets duly published from various services offered by RDF on the semantic web. On the contrary, there are other services which render RDF dump directly and is queried by means of a triple store. This approach could be the one best way to directly embed RDF over the Blockchain. Numerous virtual RDF services enable data linking with the fusion of multiple data sources. As a result, data links can be created dynamically or stored in a separate location.

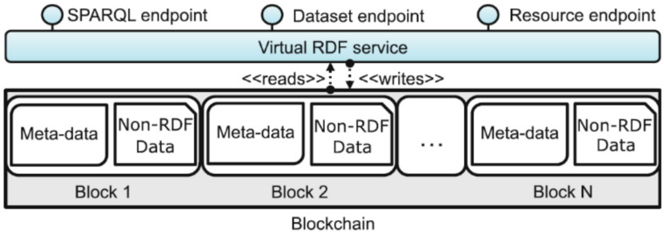

Fig. 3. Virtual RDF service orientation - representing Blockchain publication

In this approach, the data from the blockchain, specifically the RDF virtual data, can be merged with data from another source, and ontology mappings can also be integrated. One drawback of this is that it relies on an external service to create virtual RDF. The paper also states that the earlier research papers from the researchers have not defined any services rendered from a blockchain using virtual RDF. Hence, this could enlighten the core areas of researchers to work with the ideology behind the paper. This can enhance an enthusiastic approach to all research domain to learn more with blockchain and semantic web technology.

4.4 An External Pointer in the Blockchain

DNS problems are more violent in RDF. This is an important glitching aspect to store voluminous data conflicting with similarity of values in the data sets. This can be effectively achieved by allocating distinct and unique identifiers to all the available data fragments from the RDF datasets. Blockchain Hashing [3] is one among the common criterion to handle and store all relevant triplets of RDF data sets. All the unique featured triplets are hashed in to a single function by the RDF. Besides, this enhances security measures over the data. Alternatively, this could be an additional identifier which is independent of DNS system that works independently. It also enhances the appropriate identity of the subjects and URI's. Figure 4.

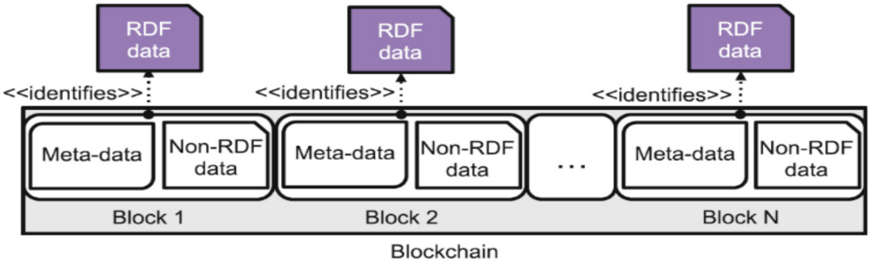

Fig. 4. RDF format over Blockchain plotting identifiers.

In the current context, the Semantic Web technologies do not provide any benefits to the blockchain. Instead, it is the Semantic Web technology being enriched from the features of block chain to meet the requirements and demand. The Fig. 4 elaborates the use of RDF with non usage of identifiers from the DNS source. This ensures the utility of resources are effectively used with out depending on the DNS. One of the advantages is that it is independent from DNS fetching better scope and availability of data.

4.5 Blockchain Referencing Another Blockchain

In this particular situation, there are two separate blockchains, as depicted in Fig. 5. One of these blockchains is utilized to determine RDF resources that are stored in the other blockchain, using any of the methods described in this section. Consequently, the RDF data in this scenario is unchangeable, easily understood, and possesses dual identification. The dual identification process is recognized by means of hash functions and other URI's being used from the consecutive blockchain. Thus, the semantic web gains advantages for the data redundancy.

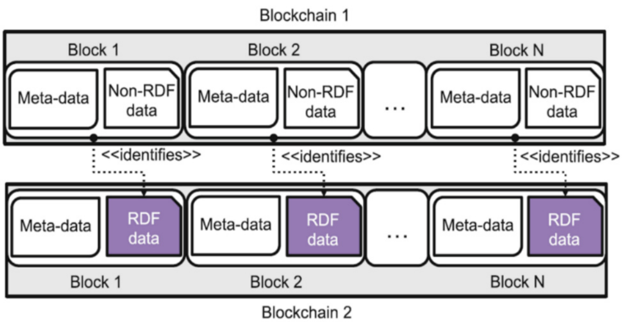

Fig. 5. Stacking of RDF chains using Blockchain

4.6 Semantic Blockchain

Figure 6 shows a situation where a blockchain implementation is created with the intention of incorporating Semantic Web technologies right from the start. Although there is no existing implementation like this at the moment, considering the potential advantages that the Semantic Web and blockchain can bring to each other, it is likely that someone will propose such an implementation. This approach would provide all the benefits we have discussed so far, from both the perspectives of the Semantic Web and blockchain.

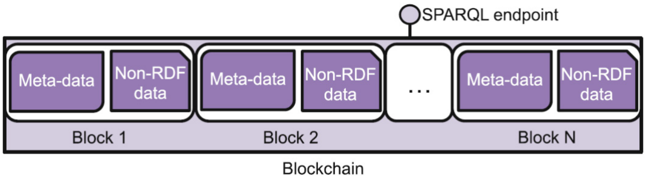

Fig. 6. Semantic Blockchain Implementation system

5 Conclusions

Blockchain technology has become increasingly important in solving problems across various industries. Researchers are showing great interest in integrating blockchain with the Semantic Web. This study examines the advantages that both blockchain and the Semantic Web can offer each other, and further clearly demonstrated various methods for combining the technologies with pros and cons. The proposed method clearly projects a basic idea for the combination of semantic web with block chain technology. Combinatory factors of at least six are mentioned to help make use of the applications. The future scope of this ideology can be great advantages in the growing demands of the industry and market.

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