Advances in the applications of blockchain technology

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Abstract

The aim of this paper was to undertake a brief qualitative review of exploratory nature on the current and future scope of blockchain technology applications. After discussing the basic aspects of the technology in some details, various applications listed and discussed by various authors were discussed. Some newly emerging applications were also discussed.

The utility of blockchain technologies in many fields arises from the absence of requirement of a third-party trust (which involves a transaction cost), public ledger system ensuring complete transparency, creation, storage and access to information ensuring transparent, safe and secure transactions with privacy protected fully. Limitations of lack of general understanding, government support and regulations and some proneness to hacking are the main limitations. All the discussions point out to (a) there is immense potential of blockchain technology for applications in a variety of situations, (b) already lot of work is being done on many of relevant applications, and (c) immense scope for research on blockchain technology for newer applications.

Keywords: Blockchain technology, Applications, Review, Advances

Introduction

This paper aims at a brief exploratory qualitative review of blockchain technology and its actual and promised applications in various fields. First the basic characteristics of blockchain technology are explained. This is followed by discussions of various applications of blockchain technologies already in use and promising ones being tried now. New researches on new areas of applications have also been discussed. The review ends with conclusions derived from these discussions.

What are blockchains?

Blockchains are distributed, decentralised digital ledger. They use virtual currencies as a method of transmitting funds and logging them. Block chains were developed as a solution to the flaws of the current banking systems. Charging transaction fees by banks (acting as third parties) is considered unnecessary. Delays of days happen in the case of many transactions, which is not liked by blockchain technologists. Real time transactions are made possible by blockchain technologies and banks do not have any role in this, thus depriving them of transaction fees, which saves cost for the actors of the transactions (Williams, 2018).

Some historical details about blockchain technology are given in Lafaille (2018). People came to know about blockchain technology when it was used in the well-known cryptocurrency, Bitcoin. However, it was originally developed by Ralph Merkle as a hash tree, termed as Merkle Tree and was patented by him in 1979. It functions as a data handling and verifying application between computer systems. It was necessary in peer-to-peer computer networks to validate data to ensure no changes or alteration occurred during data transfer. The architecture of this hash tree is given in Fig 1 reproduced from the article.

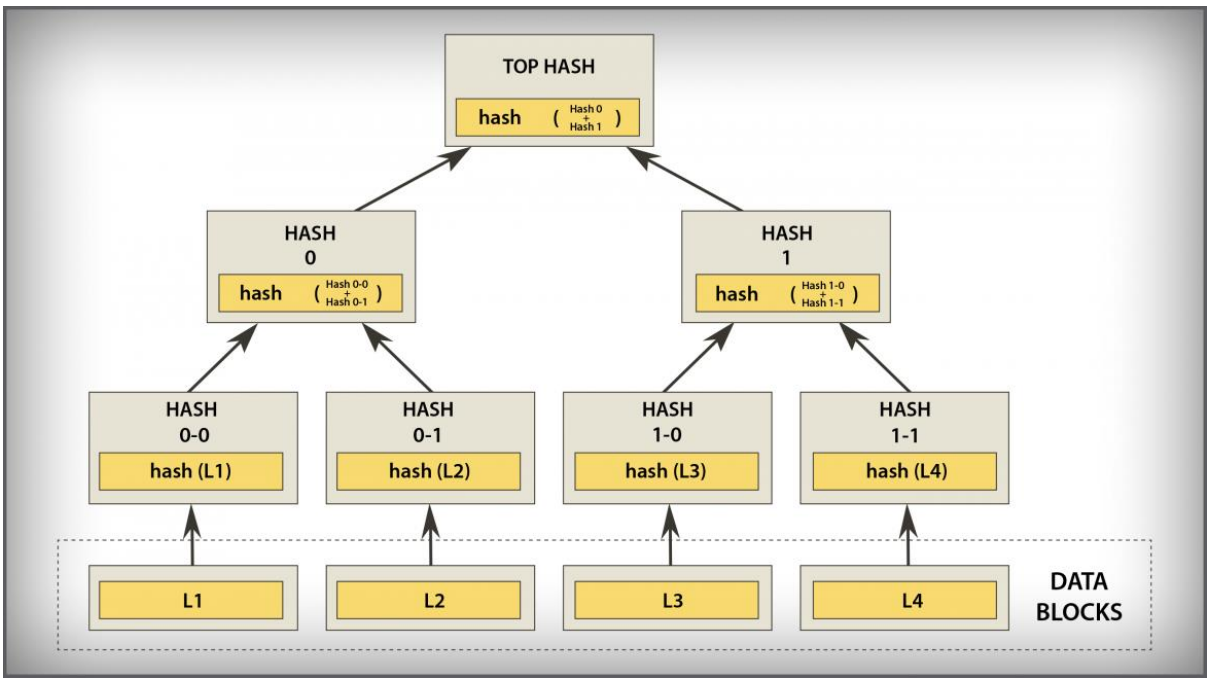

Figure 1. Architecture of Merkle Tree (Lafaille, 2018)

The Merkle tree was used for creating a secure chain of blocks in 1991. It consisted of a series of data records, each connected to the one before it. The latest of the chain will contain the latest record of all data records till that point of time. The blockchain technology was born in this manner. In 2008, Satoshi Nakamato conceptualised a distributed blockchain (Nakamoto, 2008), as the scientic basis of the first cryptocurrency, Bitcoin. The blockchain was to contain history of data exchanges in a secure manner, time-stamping and verification of each exchange through a peer-to-peer network and a system of autonomous management without a central authority. Cryptocurrencies beginning with Bitcoin and other later ones use this technology.

In blockchain, all data exchanges are recorded. The data records are called ledgers and data exchanges become transactions when applied to cryptocurrency. Every transaction added to the ledger is a block. A distributed system is used for verification of transactions through peer-to-peer nodal networks. The signed and verified transaction cannot be altered in any manner.

In actual operation, cryptographic keys are used by the person entering into a transaction. The key consists a private key and a public key. The public key is for identification of the person by others. Private key empowers authorisation of the transaction through digital signature. Both keys are used together as digital signature for authenticating the transaction. A typical transaction using these keys, is given in Fig 2, reproduced from Lafaille (2018). In cryptocurrencies, the public key is the wallet address. The private key is used for authorisation of transfers, withdrawals, deposits on the digital assets like cryptocurrencies. Safe keeping of private key is important. Anyone else having access to this key can use it for accessing the digital assets and do whatever he/she likes, and this is highly risky.

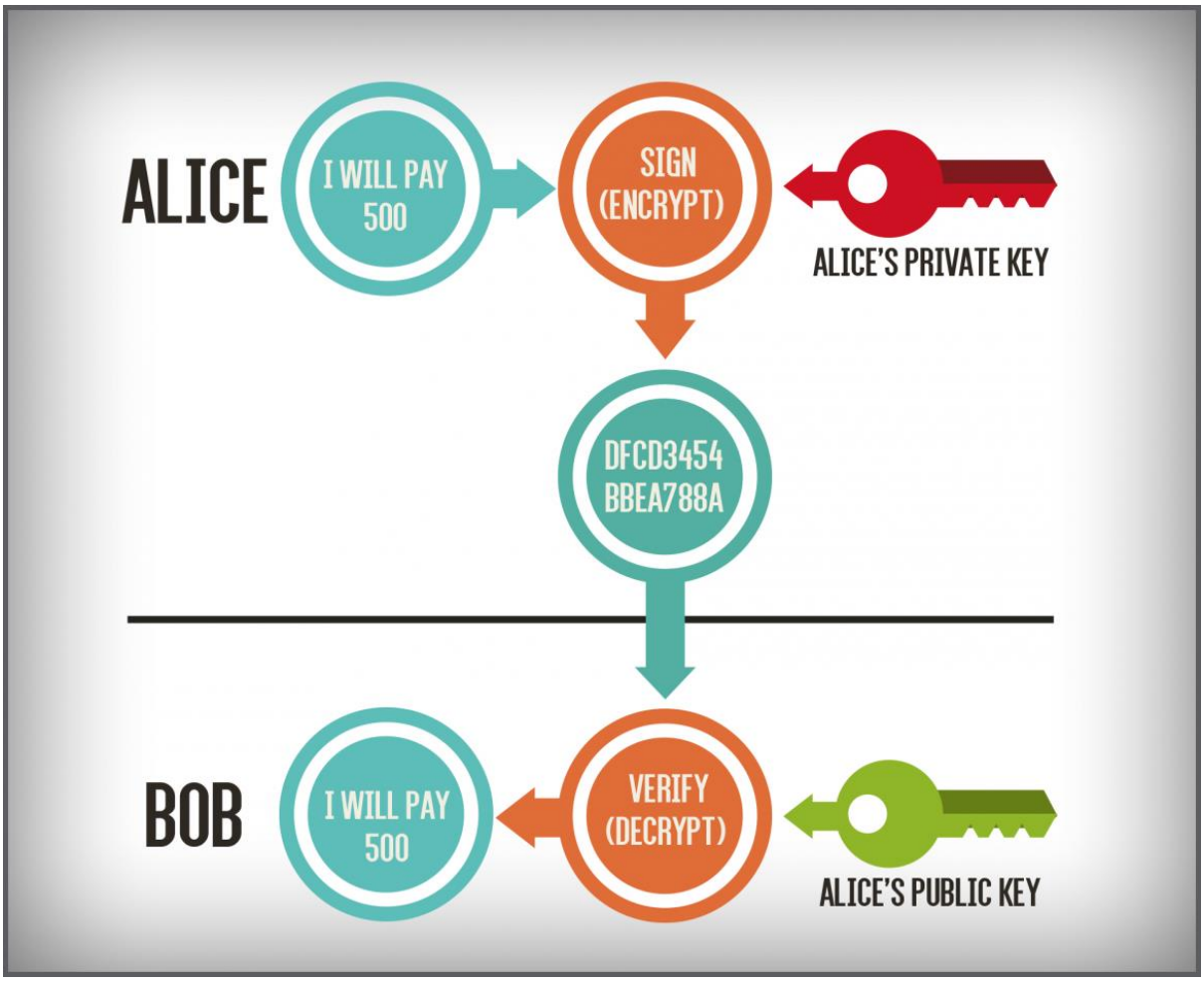

Figure 2. How the private and the public are USD in blockchain technology (Lafaille, 2018)

In a typical case, a signed transaction is also authorised by A using his digital signature consisting of both his private and public key. When A is sending X amount to B, the transaction appears as- A sends X amount of a cryptocurrency to B. The public key of B is used as his address. This transaction is added to the ledger of that blockchain. It will have a time stamp and a transaction identity number. The transaction is broadcasted to peer-to-peer network of nodes, which are, in fact, other digital units. Thus the transaction is acknowledged and entered into the ledger. The same data exist for each transaction: a digital signature, a public key, a timestamp, and a unique ID. A schematic view of these transaction processes given by Lafaille (2018) is reproduced in Fig 3.

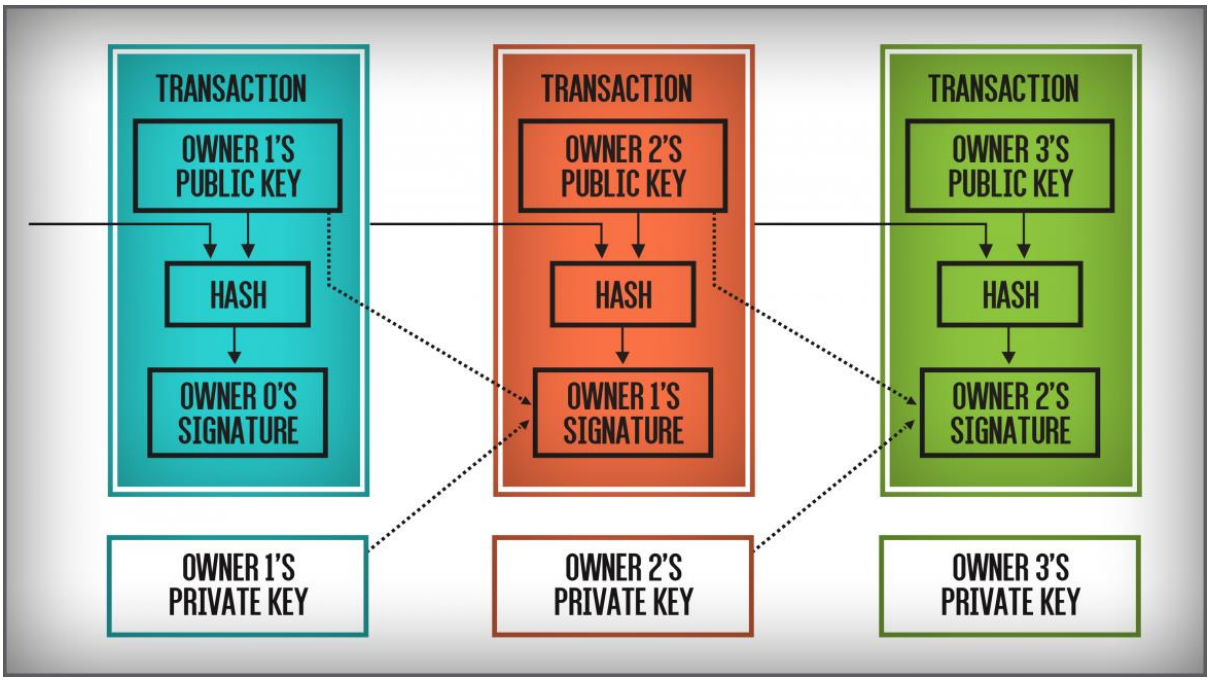

Figure 3. Schmeatic picture of transaction processes in a blockchain (Lafaille, 2018)

Although blockchain technology has merits, it has some limitations also. People who do not have technical knowledge may be sacred away by the jargons used in this technology. Transfer, buying and trading of cryptocurrencies involves a transaction fee. This is one of the issues blockchain technology wanted to avoid. Some security flaws may seriously interfere with the transactions.

There are a number of recent useful reviews (Crosby, Pattanayak, Verma, & Kalyanaraman, 2016; Pilkington, 2016; Yli-Huumo, Ko, Choi, Park, & Smolander, 2016; and Zheng, Xie, Dai, Chen, & Wang, 2017), on blockchain technology, research on the topic and some of its applications.

In the paper by Zheng, Xie, Dai, Chen, and Wang (2017), provided a more technical description of blockchain technology. Blockchain could be regarded as a public ledger and all committed transactions are stored in a list of blocks. This chain grows every time when a new block is added. The technology uses asymmetric cryptography and distributed consensus algorithms for high levels of security and ledger consistency. A more elaborate diagrammatic presentation of how a blockchain works by these authors is reproduced in Fig 4. The processes are essentially what were described in Fig 3 above.

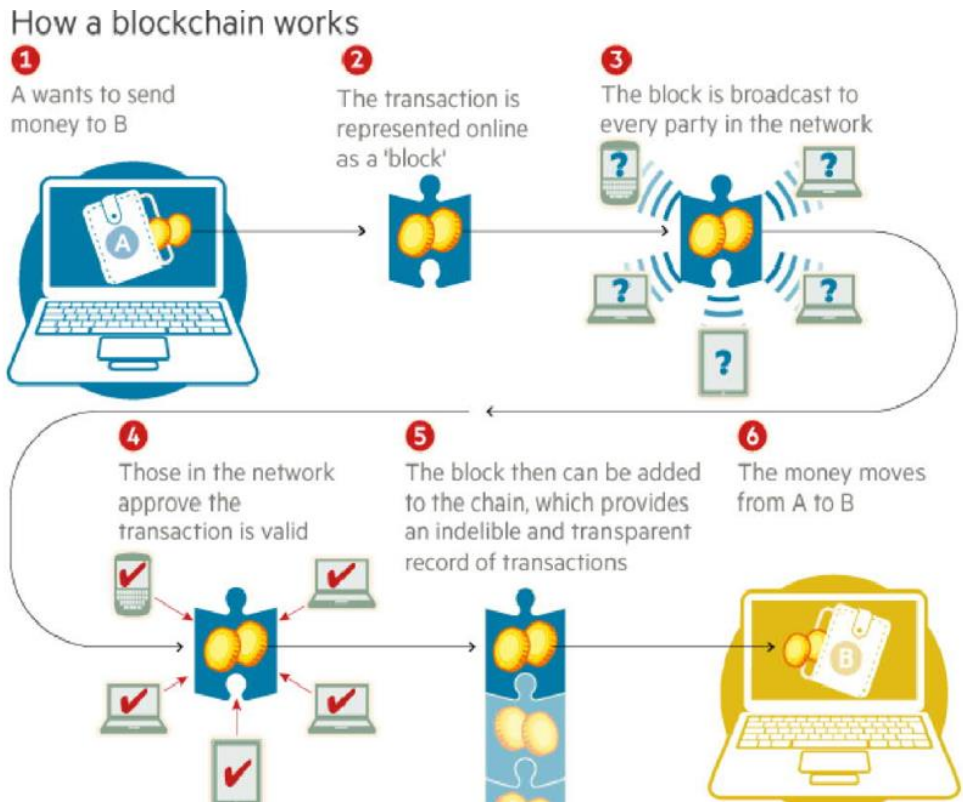

Figure 4. Blockchain Transaction Process (Zheng, Xie, Dai, Chen, & Wang, 2017)

The process of adding validated transactions into the blocks has been given Fig 5, reproduced from Zheng, Xie, Dai, Chen, and Wang (2017).

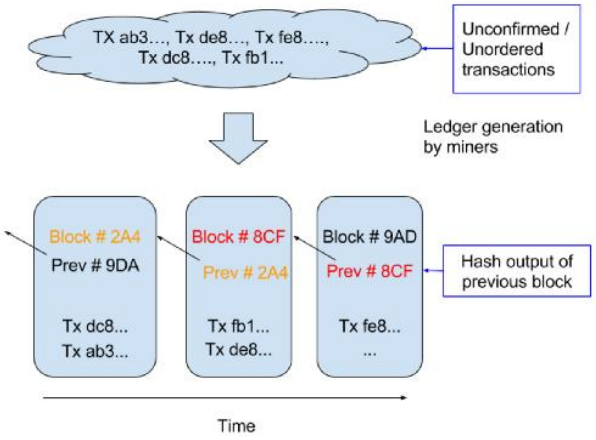

Figure 5. Process of adding validated transactions into blocks (Zheng, Xie, Dai, Chen, & Wang, 2017)

The above background about the blockchain technology is adequate to understand what it is and how transactions are entered, recorded and secured. Now the applications of blockchain technology are explained in the following sections.

Applications of blockchain technologies

Many articles, including the above cited reviews, describe multiple applications of blockchain technology.

In their article, Zheng, Xie, Dai, Chen, and Wang (2017) noted that the key characteristics of blockchain technology are decentralization, persistency, anonymity and auditability. With these traits, blockchain can greatly save the cost and improve the efficiency. These advantages make it possible to use blockchain technology in a number of financial and non-financial applications. Some of the already used applications are smart contracts and smart properties. Avoiding third party for trust may seem a direct threat to financial institutions. On the other hand, some of the leading global banks are researching on how blockchain technologies can be used by them as most secure means of financial transactions. Proofs of records are needed in many non-financial needs like healthcare, legal documents, royalty for music, notary, private securities, and marriage licenses. Such applications are supported by any of the three approaches. One is alternative blockchains using the algorithm to achieve distributed agreement on a specific digital asset. Sharing miners with a parent network (like that of Bitcoin) leads to merged mining. These can be applied in DNS and SSL certifications, file storage and voting. Coloured coins use blockchain technologies to create digital assets other than cryptocurrencies. Sidechains backed by strong cryptocurrencies like Bitcoins are possible. Many leading companies in various sectors are testing applications of blockchain technologies for their own purposes like financial markets. These include private securities, NASDAQ Private equity, security exchanges, decentralised prediction markets, digital tokens as assets, insurance, certification and transactions of valuable goods like jewellery, gold and diamond. In the case of non-financial applications, public notary services like document authentication, stamping, clearing house protocols, iOS application of block notary for existence proof for any content, crypto-public notary, authorship authentication, decentralised storage, decentralised internet and internet of things and anticounterfeit solutions. Scaling up of current blockchain applications, migration from current traditional to blockchain systems, government regulations, room for fraudulent activities and increasing hacking threats due to quantum computing abilities are some of the problems in this technology. Similar applications were listed by other reviewers also.

The maximum of 20 applications have been discussed by Williams (2018). Many of these uses are being tested b Dow Jones in small scale projects and controlled demonstrations. The applications include-

1. Payment processing and money transfers

Blockchain expedite transfer of funds with validation occurring within seconds in the round the clock, throughout the year, operation of the system.

2. Monitor supply chains

Blockchains are convenient systems to monitor supply chains. As paper-based trails are avoided, pinpointing inefficiencies in supply chains can be done rapidly. This is made possible by the ability to locate items in real time. The progressive monitoring of quality as the products move from one point to next till consumer can be achieved. Both business and consumers can be benefitted by this application.

3. Retail loyalty rewards programs

Retail experience of consumers can be enhanced by blockchain technology. A token-based system to reward consumers rapidly in real time is possible. Storing these tokens within a blockchain will act as incentives to attract the consumers to the same store for repeated visits. Frauds and wastes, which are common in paper-based systems, can be eliminated.

4. Digital IDs

Millions of people in this world face the challenges of not having a proper identity. Companies like Microsoft are trying with creating identities with authenticator applications. Such methods provide control for the users to control their identities. People in poor countries can access financial services and even get funds for own business.

5. Data sharing

The cryptocurrency, IOTA, launched a Data Marketplace in November 2017. Blockchains can be used for sharing or selling unused data. Most organisations have much unused data. Blockchains can store such data as an intermediary store and free space for organisations to store fresh data. IOTA already has 35 participants, including Microsoft, to offer feedback.

6. Copyright and royalty protection

Copyright and ownership laws of things like music have become unclear. Spread of internet has given opportunity for many people to access such materials without proper authorisation. The blockchain can provide real-time and transparent royalty distribution data to musicians and content creators.

7. Digital voting

Fraudulent voting can be prevented using blockchain technology. It enables recording votes digitally, which is sufficiently transparent for regulators to notice any change in the network. Here, ease of voting is combined with unchanging nature of the technology to ensure that the recorded vote is counted.

8. Real estate, land, and auto title transfers

As said above, blockchain avoids paper, as paper trails may be confusing. The transfer document for buying or selling a house, land or car can be digitally stored by blockchain technology in its network. A transparent view of the title deed and clear picture of legal ownership are made possible in this way.

9. Food safety

Blockchains can trace the food from its origin to the plate. The immutable nature of blockchain data allows tracing of the transport of foods from their origins to supermarkets. If there is any contamination of any product, blockchain can help to trace the contaminant source of the affected supply of food rapidly.

10. Immutable data backup

Cloud sourcing are not free from infrastructure or hacker problems. Blockchains can be used either as an alternative or an additional (to cloud storage) method to store data. Boeing is already considering this possibility.

11. Tax regulation and compliance

This is applicable to transactions which are suspicious and may attract legal action if found guilty of violating tax laws. Use of blockchains to record their transactions ensures demonstration of compliance with regulatory requirements. This is due to the transparency and immutability of blockchain technology, which makes the transactions clear records.

12. Workers' rights

International Labour Organisation says that about 25 million people are working as forced labour. Coca-Cola and US State Department are working together to create blockchain registries of smart contracts with protocols to verify, facilitate and enforce contract to improve labour policies and employers to comply with standards of labour treatment.

13. Medical recordkeeping

Electronic medical records are being used by healthcare institutions for a long time now. But, blockchain technology makes it even more secure and convenient. Patients who have access to their data, can also determine who else can share these data. Thus, there is an additional layer of protecting patient privacy.

14. Weapons tracking

There is no control on keeping arms by private persons in certain countries. Many criminal and terrorist activities are encouraged by this laxity. Blockchain technology offers a method of keeping permanent and transparent records of arms sale transactions. These records can be accessed by security agencies to prevent crimes and terrorist attacks.

15. Wills or inheritances

Another use of blockchain technology is keeping digitally made permanent wills, instead of paper. Used with smart contracts, wills become clear instruments of dividing inheritances based on criteria like grandchildren reaching a certain age.

16. Equity trading

There is every possibility of blockchains replacing current platforms of equity trading. Instant network validation and settling of transactions avoid the waiting periods of days and weeks to settle account, access funds and reinvest.

17. Managing Internet of Things networks

Cisco is already trying with blockchain-based application to monitor the internet of things (IoT). IoT denotes wireless connections of devices to send and receive data. These applications can determine how trustworthy the devices are continuously as devices enter and leave networks as in the case of smart cars and phones.

18. Expediting energy futures trading and compliance

The blockchain applications here are similar to those in equity trading described above. The technologies help in futures trading, logging their resources and comply with regulations.

19. Securing access to belongings

Smart contracts can be customised to a specific business or customer needs. Blockchain can be used as a method to access house or car to service technicians. As the digital key for access is only possessed by the owner, others cannot access without permission.

20. Tracking prescription drugs

Blockchain technology can be used for transparent tracking of prescription medicines. Prescription returns happen frequently. Counterfeit medications also happen frequently. In such circumstances, blockchain helps pharma companies to track their products based on serial and/or batch numbers and ensure that consumers are getting the original product and not fake ones, when they buy from the pharmacy. Merck is now trying out this system.

Notably, none of these applications mention cryptocurrencies, but are purely about blockchain technology. However, where funds are involved, it implies cryptocurrencies.

Other promising applications researched

High levels of information technology usage can be seen in the case of smart cities. These are used to integrate and manage physical, social, and business infrastructures, so that better services can be provided to its people. Efficient and optimal utilization of available resources also needs to be ensured. Cloud computing, internet of things and interconnected networks are used for these purposes. However, information security and privacy are challenged by digital disruptions. Biswas and Muthukkumarasamy (2016) proposed that integration of blockchain technology with smart city technologies can solve this problem, as shown in Fig 6, reproduced from their work.

In the case of food safety applications, a Chinese work by Tian (2016) showed that an agri-food supply chain tracing system using blockchain technology along with RFID offer great promise.

From a political perspective, blockchain technology challenges traditional concepts of state authority, citizenship and democracy. In his paper, Atzori (2015) discussed how blockchain technology and decentralised platforms become hyper-political tools and manage large scale social interactions and other activities and dismiss central authorities. Dominant power of private powers in distributed systems may lead to disempowerment of general public. This can lead to a stateless global society in the hands of a few global private economies. Therefore, decentralization through algorithm-based consensus needs to be considered as an organizational theory rather than as a political theory.

The applicability of blockchain technology for machine-to-machine interactions to establish an electricity market in chemical industry was explored by Sikorski, Haughton, and Kraft (2017). Two electricity producers and one consumer were considered in the scenario. Realistic data from flow sheet models were provided to all components. The concept presented by the authors is reproduced in Fig 7.

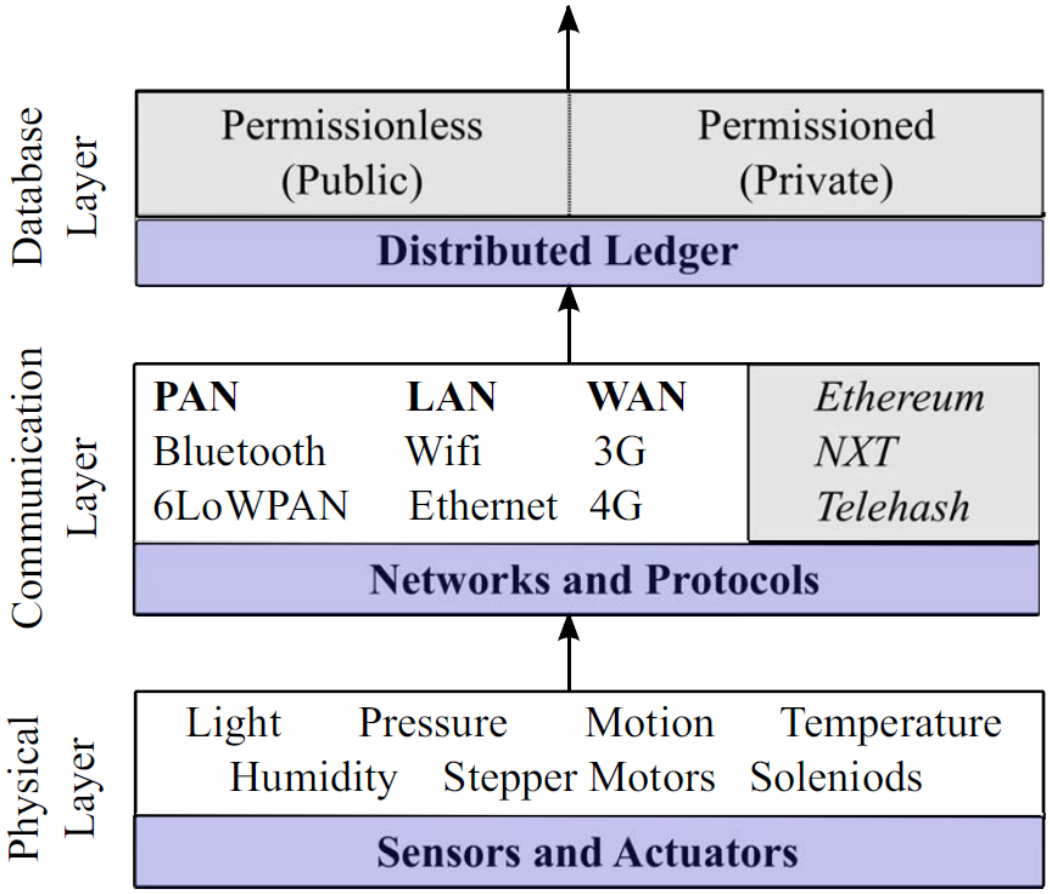

Figure 6. Smart city security framework with blockchain technology (Biswas & Muthukkumarasamy, 2016)

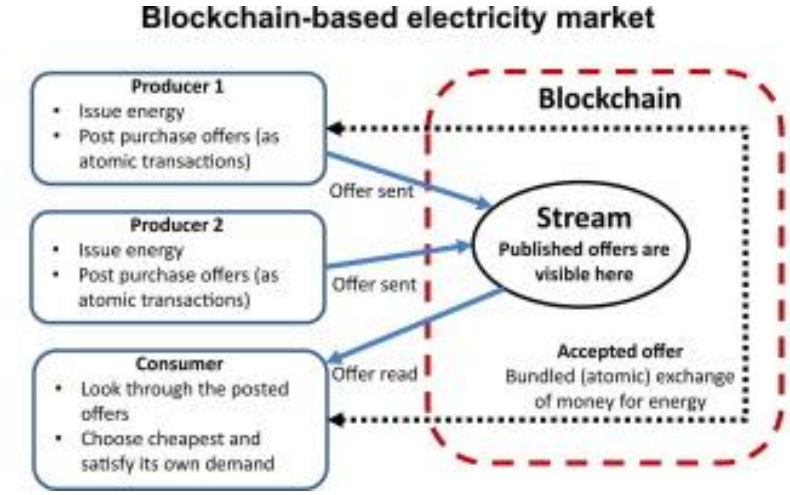

Figure 7. Blockchain technology in internal electricity market of a chemical industry (Sikorski, Haughton, & Kraft, 2017).

Intrusion detection systems (IDS) are used for identification of cyber threats and security breaches. To enhance the capability of single IDS, collaborative IDS systems have been developed. Management of their data and trust are still problematic. According to Meng, Tischhauser, Wang, Wang, and Han (2018), blockchain technology offers solution to this problem due to its capabilities of data storage integrity and transparency.

The World Food Programme (WFP) launched its Building Blocks blockchain initiative in January 2017. In the revised system of giving access to foods to refugees in Jordan, blockchain technology complemented the current digital platform and approach. The refugees use the cash in the same way as earlier. But back-end data processing became more efficient with blockchain technology. The identities of the beneficiaries could be confirmed, and cash was distributed without relying on costly verification processes required to be done by banks and other institutions. Iris scans were used by local vendors to identify the beneficiaries and sold the required food against cash vouchers or debit cards given by the banks after creation of accounts for the beneficiaries. The banks were paid by the WFP programme, out of which the vendors were paid for their sales. These findings were reported by Zambrano, Young, and Verhulst (2018) who evaluated the project.

Conclusions

Blockchain technology is much more than cryptocurrencies like Bitcoin. The technology has several applications due to its characteristics of doing away with third party trust, creation and storage of data securely, protection of privacy and public ledger system offering complete transparency. There are limitations of acceptability primarily due to lack of awareness, lack of government and legal supports and some proneness to hacking.

New methods of using blockchain technology in hitherto unknown fields are being found by research and many global initiatives are already trying many of these applications. The future of blockchain technology appears bright both as supplementing traditional currencies and as their replacement at least in certain situations.

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