An Overview of Distributed Ledger Technology and its Applications

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An Overview of Distributed Ledger Technology and its Applications

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Abstract— With the release of Bitcoin in 2008, the technology behind it, Blockchain which is based on Distributed Ledger Technology is getting popular day by day and there is continuous development and improvement in Distributed Ledger Technologies. In this paper we have not restricted ourselves to Blockchain and we have introduced some popular Distributed Ledger Technologies, a little bit about their technical implementation and areas where it can be used to make workflow easier, efficient and transparent. A number of publications and organizations websites and blogs have been analyzed to find the best practical applications of Distributed Ledger Technologies and various companies working on its implementation.

Keywords— Distributed Ledger Technology, Bitcoin, IOTA, Nano, Radix, Directed Acyclic Graph, Hyperledger, nonce, Merkle Tree, Sharded Distributed Database.

I. INTRODUCTION

In the Early days if anyone wanted anything which they did not have they used to barter that with the goods which they possessed. After that peer to peer exchange of goods took place using coins, made up of metals having some real value in it. Since carrying coins was difficult from one place to another, so people started using third parties who were present in different locations. They used to take coins from one party and in return give a written proof that they have collected so much coin and it is safe with them. After that the written proof was given to another party. Now the party might exchange that written proof for coins. This completes the transaction cycle. With time the exchange of coins was fully eliminated and only exchange of written proof between different parties remained in practice. These written proofs are known as bank notes which are given by the banks.

With the advancement in technology now exchange of money takes place over the network and there is no physical transfer of anything but just the update of database entries that is controlled by central authorities mainly banks operated by the government. Also for proper settlement of transactions between two unknown parties, we need a trusted third party and in case of conflict this third party resolves the issue between both the parties.

There are many problems having a third party for settling the transactions. Firstly, these third parties charge for the services they provide. Secondly, it takes time for the

transactions to settle e.g. for credit card transactions it takes 3-7 days for the completion of the transaction. Third problem involves the full control of the third party on the transactions. They can invalidate any transaction at any moment of time to serve their purpose. Fourthly, this third party can monitor all the transactions that are taking place between different parties. And lastly there is one central authority so if it is hacked or compromised, then the whole system will collapse.

All these issues can be resolved by using the idea of Distributed Ledger Technology (DLT). Central authority is eliminated in DLT and peer to peer transactions occur directly. All the transactions are maintained and confirmed by the whole network of peers. There is no or minimal fee for the execution and verification of transaction. Settlement of Transactions between two corners of the world takes place within minutes. All the recorded transactions are immutable that is, no one can alter the transactions once added in the ledger. To keep our money safe while travelling we distribute money in different pockets so that even if a thief is able to pickpocket he can't steal all money at once similarly in DLTs several copies of ledgers are maintained so as to make changes attacker has to hack every node in the network at the same time which is very much difficult because unauthorized change in ledger will alert other users immediately. Also, all the transactions are pseudonymous and it is very difficult to track the individuals involved in transactions which provide trust in the system.

One of the foremost DLT is Blockchain. Blockchain is thought of as a linked list of blocks containing transactions. New block contains the hash of previous block which contain the hash of the previous block and so on. Cryptocurrencies like Bitcoin [1], Etherium [2], Litecoin [3], Ripple [4] etc. are based on Blockchain. Another type of famous DLT is based on Directed Acyclic Graph [5] in which transactions are saved on nodes and new transactions are added based on some algorithm like in IOTA [6] transaction will be added after validating two other transactions. IOTA, Nano [7], Hashgraph [8] etc. are some of the applications of DAG based DLT. Another type of DLT is known as Radix [9] in which a distributed database is used to store transactions.

In section II we have listed the main class of technologies behind distributed ledgers and how their implementation is different than others. We have also listed transactions per second for the different products based on different type of DLTs. In section III we have analyzed various applications of distributed ledgers and how they can be helpful. Initial use of DLT was focused on financial services specially cryptocurrencies but with time it is realized that DLTs can be used in Voting, Healthcare, Insurance, IOT, Supply chain etc. In section IV we have concluded our paper.

II. FUNDAMENTALS OF DLT

Different types of DLTs have different implementation of ledgers, but they are categorized as permissionless public shared systems like Bitcoin, they can be permissioned public shared systems like Ripple or they can be permissioned private shared systems [10] like Hyperledger. In this section we will discuss a little bit about the technologies behind Blockchain, DAG and Radix.

Blockchain:
Blockchain is the most famous DLT and Bitcoin is the most famous application of Blockchain. In Bitcoin network if someone requests for a transaction, then that transaction is broadcasted on the network of connected computers known as nodes. These nodes verify the transaction and if valid, it is kept in transaction pool. There are some special nodes known as Miners, they are responsible for creating and adding the new block in the Blockchain. Depending on the ledger, work of the miners varies. In case of Bitcoin one block is made up of hash of the previous block, timestamp, some number of transactions, summary of transactions in a form of Merkle tree [11] and nonce. These miners take a certain number of transactions from transaction pool and continuously apply the hash function on them by changing nonce which is a number used to find a special type of hash e.g. hash starting with certain number of zeros. This is known as proof of work[12] consensus mechanism. Once Miner finds the hash, the newly constructed block is broadcasted on the network. Now nodes verify the block by applying the hash function with the given nonce. If a majority of the nodes in the

network finds that block as valid then that block is added in the Blockchain and miner will receive an incentive in the form of Bitcoin that gets reduced to half after 4 years. Initial incentive was 50 Bitcoins and now it is 12.5 Bitcoin.

Merkle tree is a tree data structure in which leaves contain a hash of transactions, now hash of these leaves are paired and hashed again, which will become parent of those leaves and this process continues until the root of the tree. So if any transaction is updated then the whole Merkle tree is updated, resulting in change of hash of the block. As every block contains the hash of previous block so if transaction of any block is updated then whole chain has to be updated which is a lengthy process and it's not possible to update all the ledgers distributed within the network that makes it immutable.

The method of finding the nonce is one among the consensus mechanism referred to as Proof of work. Other consensus mechanism includes Proof of Stake[13] in which a person can mine only if he can show ownership of certain amount of coins, Proof of activity [14] which is a mix of proof of work (in the initial phase) and proof of stake, Proof of capacity or Proof of storage [15] in which to become a miner a person has to share his unused disk space etc.

There is a rapid development on how the Blockchain technology is getting used in various applications. Initially blockchain was used in cryptocurrencies only and in terms of technology this is known as Blockchain 1.0 and its main outcome is Bitcoin. Next there is introduction of smart contracts in which rules can be defined in the transactions that will be executed in distributed ledger, this is known as Blockchain 2.0. Next innovation is the introduction of new Internet in which everything will be on Blockchain like social networks, IoT etc. This is known as Blockchain 3.0.

***Directed Acyclic Graph*:** As we have seen Blockchain is like a Linked List type of data structure which establishes a sequence, but due to this sequential nature, there is a bottleneck in the system, and we see this bottleneck in Bitcoin with a new block only being written every 10 minutes. So if the security of your data structure relies on the fact that everything be sequenced in this flow, which is a blockchain that can cause all sorts of scaling issues. So to solve the network scalability issue in distributed ledgers another type of data structure is used known as Directed Acyclic Graph. It uses a graph data structure in which there are vertices and edges which are directed i.e. all edges move in one direction and acyclic means vertices can't reference back themselves or they can't loop back themself. So unlike the linked list and the blockchain where every block has to come after one another on a main chain, in this all of those nodes are just flowing in the same direction. Also in DAGs we don't need any miner. In Table 1 we have shown the comparison between different cryptocurrencies based on

Transaction Per Second (TPS) and we can clearly see that blockchain based cryptocurrencies have low TPS and developers are working to device a method to increase TPS.

First cryptocurrency based on DAG is Nano [7] originally known as Raiblocks. Token distribution was done entirely through a faucet based system where people had to solve CAPTCHA puzzles in order to be rewarded with Nano. Now the coin is hundred percent distributed and you can't mint anymore through doing these CAPTCHA puzzles. In this, every user on the network actually maintains his own individual blockchain and together all of these individual chains form a lattice. So with every user having control over their own individual blockchain it removes the need for expensive proof of work mining or any other consensus mechanism for one big distributed ledger. It also means that each of these individual block chains can be updated asynchronously. So it has some advantages over Blockchain. Another promising distributed ledger which is based on DAG uses a technology called tangle. Cryptocurrency based on tangle is IOTA [6]. In this also miners are removed so it is fast and completely free to use. In this everyone is equal and everyone is miner. Anytime a transaction is made the issuer must help to certify two previous and random transactions. It uses a series of cryptographic algorithms along with many other sophisticated techniques to do this work. This work is done behind the scenes on such a small scale that any device could manage it without effort making it useful for Internet of things as well as micropayments in the grocery store etc. as the block chain based transactions need to wait for 10 minutes to settle the transaction. Bitcoin is trying to implement Bitcoin Lightning Network [16] so that it can be used for micro-transactions.

Hashgraph [8] is a patented technology that is owned by the Swirlds, Inc. which is also based on DAG. It also doesn't use proof of work, therefore things can go really fast and transactions can be broadcasted asynchronously. It is using a system called Asynchronous Byzantine Fault Tolerance so it's a way for the whole network to vote on which transactions happen first. This voting protocol essentially works so long as 2/3 of the validating or voting nodes are being honest and running the same consensus. This network needs a set of validators who were predefined at the beginning of the network. Essentially for open voting systems you have to have a closed set of validators because if you open it up to everybody, anybody could spin up a node and start validating and then they could collude to essentially take over the network. So on top of the voting protocol Hashgraph also has something called a Gossip protocol that picks some random nodes and then gossips the list of transactions over to those nodes but it does it in a way that reduces bandwidth. In addition to sending along the transactions while gossiping with other nodes, it also sends some network discovery features like a list of other nodes and this assists the nodes in understanding how big the

network is and also making sure that you can communicate with all sorts of different nodes randomly in a decentralized way [17]. Something important which Hashgraph claims to do is called fairness in which they can reliably give you a dependable timestamp for when the transaction actually happened by taking the median of the timestamps that are provided by nodes broadcasting transactions.

Radix Ledger:
Radix developers named the consensus algorithm and ledger architecture as Tempo. Tempo requires a network of computers connected in a peer-to-peer fashion to communicate with each other. It is a sharded decentralized, distributed database, it requires a means to chronologically order events and the order of occurrence across the network. Database sharding means partitioning of data horizontally in the database. An instance of tempo is called the Universe and the Universe contains the nodes which are participating within it. These nodes maintain either a full or partial copy, of the ledger. Collectively the nodes in the network form a sharded decentralized, distributed copy of the ledger with an amount of redundancy. Clients who wish to send events across the network such as transactions and messages can connect to any of the nodes present within the network and submit their events. In tempo there are two classes of event, there is a ledger event which is something like a transaction that changes the state of the ledger and the second is a protocol event which is a communication between two nodes executing a sequence according to the protocol. Ledger events are guarded by Asynchronous Byzantine Fault Tolerance and Protocol events are guarded by Asynchronous Byzantine Fault Detection [18].

Table 1. Comparison of cryptocurrencies with VISA and PayPal

Entity	Year	Mining Method	TPS
Visa	1958	-	56000
PayPal	1998	-	193
Bitcoin [1]	2008	Proof of work	7
Litecoin [3]	2011	Proof of work	56
Ripple [4]	2014	Consensus system	50000
Etherium [2]	2014	Proof of work	25
Etherium Casper# [19]	2017	Hybrid Proof of work and proof of stake	10,000+
IOTA [6]	2016	No Mining	1500*
Hedera Hashgraph# [8], [20]	2016	No Mining	10^6*
Nano [7]	2014	No Mining	7000*
Radix# [9]	2017	No Mining	4000*
Bitcoin + Lightning# [16]	2018	Proof of work	10^6

Yet to be released for public
* *Theoretical limit is infinite*

III.   DLT APPLICATIONS
Finance:
Bitcoin was made with the aim to remove central powers who control money, so maximum work and research were done on the financial benefits of the Distributed Ledger

Technology and its major outcomes are cryptocurrencies. Several cryptocurrencies are on circulation right now and majority of them are different from one another. Using Cryptocurrencies has many advantages. Transactions are stored in a way that can't be modified by anyone. It provides full privacy and no one can trace sender and receiver of the coin. Foreign exchange is very fast and transaction fee is very low irrespective of the locations of the involved parties. Due to removal of middlemen transaction speed between different nations is very high as well. Example of cryptocurrencies includes Bitcoin, Etherium, Ripple, IOTA etc.

If any company wants to sell its share then it has to list the company in stock exchange which is a long process, but with the invention of DLT this middle layer of stock exchange can be removed and the company can directly sell its share to the individuals to raise fund. In [21] few companies working on shares are listed that includes NASDAQ Private Equity, Medici, Coinsetter, Augur, Bitshares, Protoshares etc.

DLTs are also helpful in Insurance Industries. It will be easy to detect frauds as there will be decentralized public ledger so it will be easy to verify customers, policy details as well as transactions. Also duplicate claims can be easily detected. Since, middlemen are eliminated so it will be easy for the customer to submit claims and it will be easy for the insurer to settle the claim. With the help of Internet Of Things (IoT) and DLT everything can be automated. IoT will help to continuously monitor the state of insured things and DLT will store it in immutable fashion. Smart contracts can be written to automate claim and for settlement process. DLTs are also helpful for reinsurance as it reduce processing time and cost of placement [22]. According to [23] reinsurers can save more than $5 billion due to the use of blockchain. Currently, companies like Blink Innovation Limited, Bluzelle, Mphasis, Teambrella etc. are working on Insurance with blockchain.

Voting:
As we have seen that opposition parties in different countries regularly claims that the election was tempered. Mainly there are two methods that are used in voting, Electronic Voting Machine (EVM) and Ballot paper. Both these systems are not fully trustable. Another solution is online voting, but in voting system we need security, privacy and anonymity of voters and transparency in counting of votes which is not possible with the existing technology. All of these features can be provided by DLT and this will make democracy stronger. In [27] a secret share-based voting system on the blockchain, called SHARVOT protocol is introduced which suggest method for temper proof election process and providing anonymity to the people. Companies working on voting on blockchain Includes e-Vote, Flux, FollowMyVote, Voatz, VoteWatcher etc.

Energy:
DLTs can be useful in energy supply as well. As main advantage of the DLT is the removal of middlemen so with DLT anyone can produce energy and can sell over the network. This brings competition between energy providers resulting in ease for the consumers to get energy from anyone without getting approval from middlemen. Also, if energy production is more than usage, then that extra energy can be saved in the storage with the help of smart contracts. Another advantage is everything like how much energy transferred and consumed, all the contracts, financial activities will be stored in the immutable network so it will be easy to audit and monitor different activities and chances of scams will be eliminated. In countries like UK all domestic and commercial buildings must get energy usage certificates which is given based on the usage of electricity and how much pollutants they are emitting. For this a survey needs to be done. These certificates can be stored on DLTs and with the help of IoT, devices can be installed to monitor energy usage and waste emission and certificates can be revoked immediately at any moment in time if building violates the terms [24]. Companies like electriCCChain, Enerchain, GridSingularity, Lo3energy, Solcrypto, Solarcoin, TransActive Grid etc. are working on integrating DLT or Blockchain with energy.

Healthcare:
DLTs can revolutionize everything in Healthcare. All the knowledge associated with patient like his diseases, treatment, results from pathology etc. can be stored in one single point. So the process of diagnosing a patient will become smooth. Also, all the information is stored in a single distributed ledger so any hospital all over the world can know his medical condition if the patient gives the permission. With the help IoT real time diagnosis can be monitored and stored in ledger [25]. Another advantage is for insurance industries as records are stored in an immutable ledger so patients can't make faulty or false claims.

It will be easy to detect doctors who practice in places where they are not allowed, like is some countries if the doctor is a government employee he can't practice privately. This will improve the conditions of government hospitals. One of the main advantage is in Supply chain management. There are many frauds in the whole lifecycle of supply chain in healthcare especially in developing countries. Example of scams may include fake medicines, fake licenses, fake bills, misrepresentation of dates/location/provider of services, corruption, incorrect diagnostic report etc. All frauds in the supply chain can be easily tracked and proper actions can be taken within time if the information is stored in distributed ledger. In permissioned distributed ledger decisions are only approved by the concerned authorities and if anything goes wrong they can be tracked and liable to answer. Companies like Gem Health, iSolve, LLC, Patientory, PokitDok, Blockchain Health etc. are working on this.

Supply chain:
Removal of middlemen is helpful in supply chain as well. Now business does not need to appoint anyone for negotiating on behalf of them. Firms do not need to share confidential information with the third party. Every process will be clear and efficient and it is not necessary to wait for any kind of approval. All the deals can be written in smart contracts that will automatically handle the rest of the flow. This means that everything will be clear beforehand that will save both effort and money to the organizations. It will also be very easy for the payment settlement and delivery of the service. Frauds involved at any level can be detected easily and it will be difficult to cheat the system. Distributed ledger provides not only security but also it helps in data analytics as only relevant information will be stored in the ledger. Also moving from existing system to distributed ledger is not needed as DLT can be implemented as a layer above the existing infrastructure, so it will be easy to implement [26].Companies like Apptera, Blockverify, Luxoft, Skuchain, Wave etc. are working on this.

Music and media:
The main problem with Music industry or Film Industry is to detect the copyright violation all over the world and this is because there is no single database to store such kind of media and it's also not possible because it is difficult to make one central organization in the whole world. This can be solved using distributed ledger as we don't need a central authority, but we can store all copyrights in one database distributed over the network. Musicians or directors can easily raise money by crowd funding and anyone can buy shares using cryptocurrencies and contracts can be established using smart contracts. Also, as cryptocurrencies are present in large denominations so micropayment is easy and revenue can be directly collected and distributed among stake holders when media is streaming or downloading. It is also helpful for new musicians, singers etc. as they just have to put their media on the network with smart contract and they don't need any publisher or lot of money to get established as an artist. Artists can write their own terms and conditions over the network and generate revenue if they are not violating any copyright which will be confirmed when they submit their media to the network [27].Companies working on it are MUSE Blockchain, Revelator, UJO etc.

Property Registration and transfer:
Distributed ledgers can also be used for the registration of land, vehicles, house etc. All the registration related to one entity say car can be stored in one type of distributed ledger and their owners can sell or buy that entity by paying in the form of cryptocurrency and storing new owner information in that entity's ledger. So instead of depending on the way of payment, this method just stores the property transfer information and later it can be verified for any conflict. Another way is by having smart contracts on Bitcoin network. In this method smart contract will receive assets from both buyer and seller and redistribute that. Clearing and settlement process will be automated. Buyer and seller can track the flow of settlement. This will fully remove conflicts regarding the rights of the property and make the process faster by removing the middlemen. Companies working on this include Propy, Propify, Rentberry, ShelterZoom, Bitland etc.

Retail:
Distributed ledger technology is also helpful in retail. As discussed above, it will improve whole supply chain management, which will be helpful in Retail as well. With the help of DLTs we can store only that information about the customers which the customer wants. This will be useful for both merchant and customer as for merchant they do not ought to pay a ton of cash for data analytics and for customers it will be useful as their privacy will be increased and customers can track what is stored in the ledger, to get desired product advertisements and information about rewards or cashback etc. Distributed ledgers will also increase transparency because illegal activities or processes can be tracked because of immutable ledgers. Retailers can't sell duplicate products as whole chain of supplier can be tracked back to the origin of the product. And finally payment system will be automated and only payment will be done if the original product is received by the buyer. Companies working on that include Provenance, Everledger, Ascribe, Block Verify etc.

Others:
Distributed ledger technology can be used for identification management like voter id card, passport management, certificate management etc. It can also be used to implement various government schemes which normally fails due to the presence of middlemen and corrupt officials and politicians. Data from IoT devices and security from DLT can change the whole world and will make it a better place to live. DLTs can also be used to make cloud computing[28] better. Also DLT can work with Artificial Intelligence (AI) making each other better.

IV.   CONCLUSION AND FUTURE SCOPE

We have introduced some Distributed ledger technologies and most famous of them are based on Blockchain but due to its slow transaction per second other technologies based on DAGs are trying to replace blockchain. Overall Distributed ledger technology is new, fast evolving and as we have seen it has a lot of potential. It will definitely need some time to mature and find its presence felt all over the world. Of course, there are some challenges that needs to be tackled but this technology has the potential to change the way different organization or government operate. It can be used anywhere to replace third parties or middlemen so that it can contribute towards improvement of corrupt and inefficient system. Also now it is possible that DLT will introduce new protocols that

work over the Internet layers and bring about the changes in the way Internet works today. We have included various sectors and listed some companies and startups that are working on replacing the old systems with DLTs. It is necessary that the users and governments come together to start implementing solutions in DLT and then only we can expect a better world in the near future with increased security and auditability.

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