[[1]](#footnote-1)

Blockchain Analysis

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***Abstract*—With the rise of cryptocurrencies such as bitcoin, blockchain technology is the database that the idea is based on. Blockchain technology is a decentralized, unalterable ledger meant for peer-to-peer communication. Applications of blockchain are being further developed in the realm of finance and have begun to branch to more applications such as smart contracts and others. The goal of this paper is to provide a tutorial on blockchain technology as well as provide a working example and evaluation of an experimental blockchain database. We will provide this information via a walk-through of transactions with blockchain technology and examples of blockchain applications.**

***Index Terms*—**

# INTRODUCTION

Blockchain was born out of the question of how to securely transfer in a peer-to-peer environment. Today, when two companies perform a transaction, one does not physically hand the money over to the other. Instead, this exchange of funds is performed most likely using a direct deposit from one bank account to another. This is able to be done because of the trust that both parties have in the banks that hold their funds. It is, according to the blockchain creator, “purely peer-to-peer version of electronic cash”[18].

The basic steps for how blockchain works is that when someone wants to perform a transaction, that transaction is sent to multiple computers (nodes) that determines if a person has the funds to perform this transaction[18]. When it is determined that there are funds for the transaction to be valid, this new transaction is added to each party’s list of transactions, before completing the transaction. This list is similar to how one can look at their bank activity history and see every credit and debit performed on one’s account. The difference is that this history is not able to be changed in any way, each person’s blockchain is widely available, and the block validation algorithms are all widely known. Both of these changes are fundamental because it allows blockchain users to be completely transparent.

In short, the reason that blockchain is so practical for keeping track of transactions is that each transaction, block, has both a timestamp and a link to the previous block. Both of these features make creating a ledger showing each transaction very easy to do.

Blockchain was invented by Satoshi Nakamoto, a pseudonym for the person or group of people who wish to remain anonymous. Blockchain originally rose to prominence from bitcoin, a cryptocurrency, but it is starting to see its usefulness expanded. An example of how companies are looking towards blockchain technology today is the *Level One Project* by the Bill & Melinda Gates Foundation is using blockchain in order to show proof of credit to those who do not have bank accounts. The foundation estimates this may be the case for over 2 billion people.

Blockchain is impervious to less than stellar record keeping. In the United States, there is usually a proof of ownership available for any large purchases. However, this is not true everywhere in the world. Blockchain acts as a proof of ownership. Since it is unable to altered, blockchain is proof that a transaction took place.

# What is Cryptocurrency

Cryptocurrency is a digital or virtual “currency” which uses cryptography to secure the individual transactions. In 2009, Bitcoin became the first decentralized cryptocurrency. Ethereum, a newcomer to the digital currency industry, is becoming a large player and is set to overtake Bitcoin. These currencies are not created by a central government agency such as the U.S. dollar. Instead cryptocurrencies depend on miners to create the units of the currency and rely on encryption to ensure the validity and value of the currency[7].

Cryptocurrencies start by choosing a base unit and the individual units of the currency are created when a transaction occurs. A chain of transactions is formed when the currency is used. These transactions are encrypted and timestamped for security and transparency purposes. Take for instance Bitcoin. Bitcoin miners use computers to find a hash that connects a new block with an old block previously mined. The block is the group of entries and the chain is the hash[9].

Even though all cryptocurrencies are different, they all share some basic characteristics. They are a one-way transaction, once the transaction has been confirmed by the network it cannot be undone. They are also anonymous allowing anyone to access a “wallet.” Their supply is limited by the network which gives them value; they cannot be counterfeited. Transactions are fast, usually within a few minutes a transaction can be validated[8].

Bitcoin currently holds the largest market share for cryptocurrencies. This system works by having a large number of volunteers around the globe maintain a ledger of transactions. When an individual that holds a Bitcoin wants to send that coin to someone else, the sender announces to the entire Bitcoin peer-to-peer network and they send a coin from their wallet. This wallet has both a public and private key. When the transaction is initiated, the transaction is encrypted with the sender’s private key[10].

The individuals maintaining the ledger record this transaction and compare amongst themselves as an audit feature to validate the authenticity and the amount of the transaction. The ledger keepers use the sender’s public key to verify who the transaction was sent by. The wallet and the network of ledgers also validate that the sender has enough coins to complete the transaction so that the same coins are not spent twice.

The Bitcoin’s ledger keepers are also known as miners. When they have enough transactions to fill a block, they need to solve a hash first, by guessing. The miners can choose how they wish the computer(s) they are using to guess the answer to the hash. This hash is encrypted with SHA256 and becomes more difficult in relation to the number of miners trying to solve it to add their block to the chain. This is done to keep the blocks being added at a constant rate. The miner who solves the hash first will have their block added to the chain and receive a reward of 12.5 Bitcoins. This reward drops 50% for every 210K blocks added to the chain and it is expected that the last Bitcoin will be created around the year 2140.

Below is a representation of the chain where each block is filled with transactions and marked with the previous block’s hash and a Nonce.



Blockchain databases amount to another development in the line of databases structure designs. Early on, unstructured and structured databases were developed into distributed databases with the need for larger datasets across nodes. The blockchain database is another piece to this evolutionary timeline of the database in the form of a distributed ledger database. The distributed ledger database includes cryptography and decentralization that share facts which is important in a trustless environment.

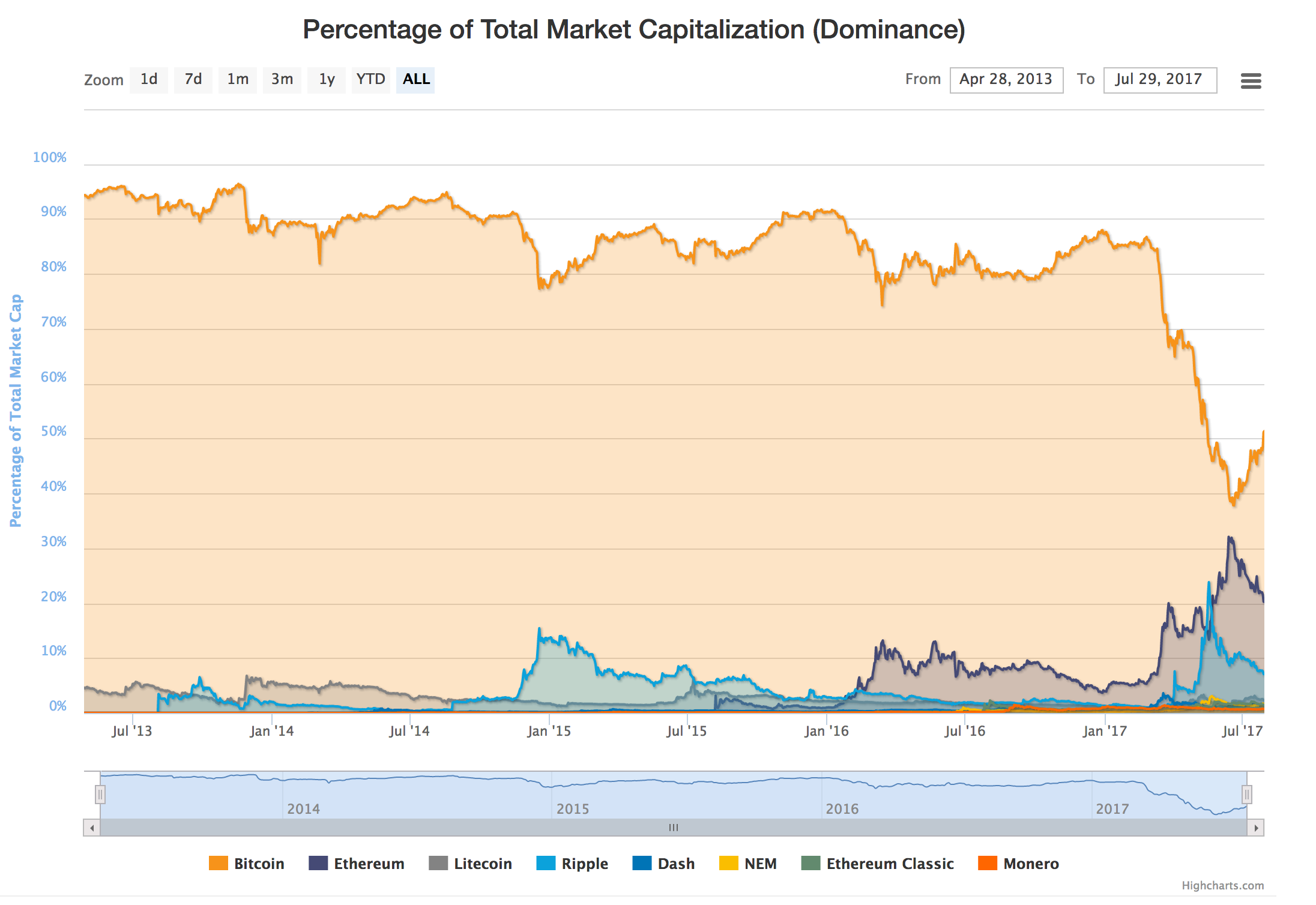
Blockchains don’t do anything new with relation to database systems but they do somethings differently[23]. Feature by feature analysis goes back and forth between blockchain and traditional systems as to which is the better system. Decentralization is probably the largest difference between blockchain and traditional database systems. This feature allows for built in redundancy and the ability to break away from having to trust one single entity or individual to manage the data. Although decentralization is great for redundancy, it also exposes another issue which is confidentiality. Confidentiality is a feature that traditional systems have over the blockchain database. This is a direct result of the centralization of traditional systems. Finally, performance is another feature that traditional system just does better than blockchain databases.

The blockchain database performance just does not come close to a traditional databases performance. The throughput is constrained to only allow a few transactions per second. This would be unacceptable in any traditional database today. Also, it takes approximately ten minutes for a write to the database is confirmed. Blockchain databases can handle up to only a few dozen gigabytes of store while traditional databases can be dozens of terabytes. Furthermore, the network communication of these databases is not efficient. As more nodes are added the network traffic increases dramatically. For instance, just doubling the number of nodes in a blockchain database system will quadruple the network traffic[19].

So, by these standards a blockchain database, as it stands, would not be very practical for a business, especially one with a high volume of transactions. In this case, some companies are turning this idea around and adding blockchain capabilities to a standard distributed database. By making the databases scalable and have blockchain features such as immutability and decentralized control, these databases can then be utilized for enterprise systems and be complementary to platforms such as Ethereum[20].

Blockchain or distributed ledger database do provide features which traditional systems do not, presently, have. With the decentralization of the blockchain database, applications feeding of this system can then also be decentralized which provides the basis for applications such as Bitcoin. Smart contracts/property is another feature of the blockchain database which traditional system do not currently replicate. These contracts can be verified, programmatically through the blockchain. These features, blockchain, decentralization and smart contracts compiled into one system allow for trusted computer through trustless transactions. Through this system, each node on the network can trust one another due to these features being put in place[22].

Cryptocurrencies are slowly gaining more of a market share as the technology becomes more popular. The most valuable cryptocurrency is Bitcoin, followed by Ethereum, Ripple, Litecoin, and NEM. The market capitalization of Bitcoin is $45 million and Ethereum’s market capitalization is $18 million. Only the top seven cryptocurrencies have a market capitalization over $1 million. According to Blockchain Luxembourg on 07/28/17, the average market price across Bitcoin exchanges was $2,781.63 and 244,289 transactions were performed that day[24].



https://coinmarketcap.com

The second largest cryptocurrency available is Ethereum, which was created in 2015 making it much younger than Bitcoin, though it is not exactly a cryptocurrency in the way that Bitcoin is. According to its creator Vitalik Buterin, it is ‘a decentralized platform that runs smart contracts’. A smart contract is an exchange of money, property, goods, etc. performed by premade computer code. An example of a smart contract is using an online stock trader to sell a certain stock you own if the price of a share reaches a certain amount. Therefore, Bitcoin is a system for using digital money while Ethereum is a system for using smart contracts and both of these use blockchain technology. Ethereum even has developed a language for writing these smart contracts: Solidity. With it, you can create the tokens Ethereum uses more easily[25].

Both Bitcoin and Ethereum use the blockchain for different purposes. Bitcoin uses blockchain in order to keep track of who owns what bitcoin, that is, it is used to keep track of the ledger. Ethereum uses blockchain in order to run code to enable the smart contracts. Also, instead of mining bitcoins, the blockchain is mined in Ethereum for tokens that are used to pay for Ethereum network services. These tokens are used as a cryptocurrency, but that is not the central part of Ethereum as it is for Bitcoin. One of the great benefits to using Ethereum is the Ethereum Virtual Machine (EVM). It acts as a universal translator for programs running using the Ethereum blockchain. It runs code of any type, though the program the running code originates from may have an effect on how efficiently the code runs[25][ethereum.org].

This is a key difference for companies that want to use blockchain technology on projects. For each different market, different blockchain techniques are available depending on if you are using Bitcoin, Ethereum, or one of the others. The primary priority of Bitcoin is security, and then speed. Bitcoin is limited though to the amount of commands that one can use, allowing less than 100 specific commands. Ethereum on the other hand needs blockchain technology for making sure that the smart contracts run as they are supposed to without any interference, delay, etc. Bitcoin has a set limit of its quantity while Ethereum does not. Ethereum does artificially limit the total amount of tokens that are added to circulation each year though. Also, bitcoins are mined while Ethereum tokens are only validated. This means be either a third party in a smart contract to receive tokens or use tokens to pay for the smart contract[25].

## Current, Future, and Conceptual Uses for Blockchain

Blockchain has uses in many different areas other than currency. Contracts, title ownership, credit history, tax records, voting; these are a few of the places that have potential to benefit from blockchain technology. Basically, blockchain can be used anywhere decentralized, immutable data is needed.

Identity: Out of the total world population of almost 8 billion, one-fifth of these individuals do not have proper identification[1]. Also, of those that do not have official identity documentation, a disproportionate amount of them are women and children [17]. This can be an issue in areas where human trafficking is an issue, mainly Asia and Africa. Without proper identification, a person can be vulnerable to trafficking, prostitution and exploitation[1]. Microsoft is collaborating with partners to establish a blockchain identity based system[1] which the goal is to provide self-owned identity to aid in mitigating the risks of not having an official identity. Their system is leveraging both Bitcoin and Ethereum to find the best solution to meet these needs.

There are many opportunities in healthcare, one more interesting use would use permissioned blockchains. These blockchains would be used for holding electronic health record (EHR) data that is available to various entities subject to the permission of the owner (the patient). This idea would tackle the problem of limited access to population health data as well as sharing data between health systems. Currently the problem with implementing this is the limit on computing power due to reduced participation in the network[13]. Another idea in regard of healthcare and blockchain is the coupling of EHR with AI in some way to calculate risk[16] although initially the availability of such data could allow insurance companies to unfairly discriminate against potential enrollees.

Fraud and illicit trading: Everledger, a London-based startup, has created a ledger which is named “Hyperledger” to track the sale of various luxurious items from start to finish, when the luxury item has been legally purchased. This is especially helpful in tracking diamonds. Currently 99% of the diamonds on the market originated from conflict-free zones[2]. But due to the paper-based system in use, fraud is remains an issue. Everledger has created a system in which the authenticity of what is purchased can be verified through the use of blockchain. Also, insurance fraud is a large issue with luxury items. The insurance company has no way to be sure the item (such as a diamond ring) has really been lost or stolen. Hyperledger allows insurance companies to make sure these items to do not come back on the market and if they do, they would be able to determine whether the item was lost or stolen.

Music industry: Using bitcoin music artists are able to control their own creative content. Due to the inherent design of cryptocurrency, there is not a one central authority which manages the ledger of transactions. Music artists would be able to publish their music to the ledger with a unique stamp[3] which would record the music owner’s right to the content. This stamp would be verifiable and visible to anyone looking at the file. This system would aid in stopping unauthorized copying of music content. BitTunes is a startup which was conceived to deal with music piracy. They allow the musician to become the distributor of their own work.

Also, using cryptocurrency would help the artists sell their product to a larger audience. Cryptocurrency such as Bitcoin and Ethereum allow transactions that are small. Without cryptocurrency, these small transactions would not be supported because of all of the transaction fees that accompany the traditional payment systems. Another benefit to the music artist in using cryptocurrency is that they will be able to immediately see the rewards for their work. Traditionally, the artist would be paid by the music label which would be in arrears. Not only would the artist be paid in arrears, they would also get a 15% cut of the total price that the consumer paid for their work. Using cryptocurrency, the artist receives approximately 90% of the amount that the consumer paid for their product[3]. Currently there are a number of startups that are providing this service to musicians through blockchain ledgers.

Land registration: In developing countries, land ownership and registration is a difficult issue to tackle. In the traditional systems, there is fraud where unregistered land can change hands without the true owner even being aware of the transaction. Sweden has started an experiment to tackle this issue and make real estate transactions transparent and also eliminate manual errors pervasive in the traditional system of land management (4). Countries such as Ghana, Honduras and Georgia have begun to test various blockchain systems in which land would be registered. This, these countries are hoping, will reduce fraud and allow banks to loan more easily since the transactions dealing with a particular plot of land would be transparent.

Almost all uses of blockchain eventually help the government. The distributed nature of blockchain necessitates a certain level of standardization in information expression and this makes it easier for governments to acquire data required to tax and impose laws. As of April 2016, a Ghana based company named Bitland Global has the mission of using blockchain for land titles and real property in order to help settle title disputes and also to bring democracy and meritocracy to investing in land[14]. Many of the blockchain uses and potential uses are relatively simple but there are some more ambitious ideas for the technology.

Utilities: Due to the inherent low cost of transactions using blockchain platforms, utilities and utility customers alike are testing the waters to see if using blockchain can be viable. In New York state, homes with solar panels are selling their excess energy captured from the sun to other customers. Utilities are investigating whether using the blockchain process can bill customers and keep the transactions transparent. Flexibility is one of the key motivators in testing the blockchain methodology. For example, a business could sell as little as five minutes of unused power during its downtime to another business that needs more power[6]. In traditional systems, these kinds of transactions would be infeasible due to transaction fees. Also, utility companies are hoping to benefit from the decentralization of electricity trades to aid in making the grid more efficient. Through blockchain technology they are looking to extend the life of their equipment and improve earnings through efficiency.

Smart cities are being considered in many places and some entities like the government of India have even developed a smart cities initiative[15]. Smart cities don’t have a clear definition but many envision these as cities that capture data related to most aspects of life in a city from the individual level to the city-wide level. This could help mitigate risks of various kinds of accidents like car accidents, structure fires, etc. This could also coordinate utilities like electricity or natural gas to help eliminate waste. Many see this as inevitable and are actively trying to develop a smart contract system that does everything that would be needed to make a smart city truly smart[16].

Another novel use of Blockchain technology is for tracking transactions of electricity on the power grid. The electrical power transmission grid in the United States consists of power lines operated by over 500 companies. Traditionally, consumers and power companies have only had one-way transactions (power company sells electricity to consumer). Increasingly, consumers have begun to generate a portion of their own electricity using solar panels. When more energy is generated than what is consumed by the customer, it is purchased, usually by the same power company at a rate set by that power company. Because the transmission of electricity on power lines is governed by the laws of physics, the power produced and consumed is tracked by a meter the power company monitors. The electricity you consume might not be produced by the power company you pay for it, but by another company who sells the energy it produces to the company that charges you. On the corporate scale, transactions like this are commonplace, but on the consumer scale, there has been limited implementation of methods to track these small-scale transactions. Recently, several startup companies are using Blockchain technology to create a way for consumers to sell the power they generate on the open market rather than directly to the power company.

The use of Blockchain technology to track small-scale energy transactions relies on two factors that make it possible and desirable. The ability for a consumer to sell electricity they generated on the open market is made possible by the Energy Policy Act of 1992 which requires transmission line owners to allow open access to their network[6]. Technically, individuals aren't allowed to sell or buy actual electricity directly from each other, but instead sell tokens[6]. These tokens function in a similar way to how energy companies sell renewables to consumers by having them purchase a token/credit that insures the energy company will generate a percentage of their energy from renewables. The open access transmission lines in the USA coupled with consumers’ increased concern with how their electricity is generated (renewable vs nonrenewable) has created a prime market for small-scale renewable energy generation. The only component lacking was a method for tracking these transactions, which were common at the large scale but non-existent at the consumer level. Blockchain technology enables a secure, reliable transaction ledger to manage these small-scale energy token transactions.

In contrast to the traditional model of selling excess renewable energy generated by the consumer back to the power company, startups like LO3 Energy envision a micro-grid energy market that connects local energy producers and consumers. LO3’s TransActive Grid marketplace is being tested in Brooklyn, where individuals with rooftop solar panels are selling the excess energy they produce in the form of tokens to consumers in their neighborhood. These transactions are powered by a bitcoin ledger that tracks the tokens and maintains a micro-grid for the neighborhood using smart meters installed in participants’ properties. Both the producers and users benefit from this micro-grid because the prices they buy and sell at are based on the market prices that energy companies buy and sell to each other at[6].

## The Level One Project

Blockchain technology can also serve as a backbone to help improve people’s credit. The Bill and Melinda Gates Foundation launched *The Level One Project* in order to work with impoverished countries and introduce them to alternative methods to banking to help its citizens. Many people in these countries do not have bank accounts and the *Level One Project* aims to give these people access to the benefits of having a bank account, without using a bank. According to the foundation, they estimate that there are more than 2 billion people without access to bank accounts [17]. This is a massive amount of people that *The Level One Project* believes

The users of a digital currency have certain needs that are different from American banking systems. In terms of databases, people that use cryptocurrency as a primary form of currency will need a database that is ACID. The user base will be treating their digital blockchain database as cash, therefore, they will need to be able to spend their money without any wait time. In the United States, many banks say that it may take 1-3 business days for a transaction to go through. This is a non-starter for users without much money. The intended user base will need to have the option to spend money as soon as it is sent to them. The next property of ACID is Consistency. There needs to be an accurate reading of how much cash is in a user’s blockchain so users do not accidently spend money that they do not have. Again, this is not a bank account. Therefore, one cannot have a negative balance. Isolation is having each transaction separate from each other. This is important so there is a sequential guide of each transaction. This is very important to blockchain as each block in the blockchain has a link to its previous block. Finally, a requirement that the *Level One Project* has durability. If people are to rely on a blockchain database in place of a bank account or cash, it’s transactions must be permanent even if the system goes down. Inconsistencies would be very damaging to the user base if transactions did not go through and money was lost because of a database error.

*The Level One Project* considers another important factor that a blockchain database would need to implement in order to be useful. It needs to be able to seamlessly interact with existing financial infrastructure. Even if a blockchain financial tool is introduced into a country for its citizens to use, it would be useful if it cannot interact with other businesses or banking institutions. The resultant database must be able to do such functions as receive a paycheck from an employer and pay bills. This requires cooperation with governments to implement rules to allow this.

The *Level One Project* does not create digital financial services for countries do use, only to educate and assist countries that are interested in this as a way to help some of their citizens. It does however promote working systems in order to further entice governments that blockchain technology is a viable system. a few of the countries that have started implementation are India, Mexico, and South Africa using the Aadhaar Program, SPEI. and other alternative payment methods [17].

## Blockchain for data storage example

We chose to use the MultiChain API for our demonstration. Here we outline some steps for basic data storage and mention some options. Assuming MultiChain is installed on all nodes, the basic steps are to setup at least two nodes, create a blockchain, connect to the blockchain, write to the blockchain, and optionally retrieve data from the blockchain.

About Multichain

Multichain is a recently founded company dedicated to providing quick access to fully customizable blockchain technology. Some of the most useful capabilities of Multichain are managed permissions, rapid deployment, unlimited assets, and data streams. Managed permissions refers to the ability of a blockchain originator to have full control over who can access the blockchain and what kind of permissions they will have. Rapid deployment, as we will show in the next steps, is a very short series of steps that results in a fully functional blockchain. Assets are unlimited in the sense that on a blockchain a user can create assets as needed; the circumstances in which an individual would make new assets is completely up to them but the option is available. Below we will walk through the general steps to create a data stream. The data stream allows for multiple key-value, time series, or identity databases. These streams are ideal for data sharing and offer the capability of creating separate streams which can be useful for sharing keys for various cryptographic operations. One other significant property of the Multichain API is the ease with which developers can incorporate Multichain into their applications, this is much akin to the way in which protocols in the transport layer are meant to provide a seamless interface with anything being done at the application layer.

Setting up Nodes

There are different ways to do this, one is to create virtual machines. We created an SSH connection to another machine on one of our LANs to serve as a client node. It would also have been possible to forgo SSH and opt to physically use another machine on the same LAN. In a real world use we would be using nodes across networks.

Creating a Blockchain

Either node can create and initiate the blockchain. The node that does create the blockchain will be the default admin. It is also possible to make the blockchain accessible to anyone, thereby allowing anyone to append to the blockchain. As we discussed above, blockchain data storage is append only and previous entries are immutable. Blockchain is also distributed; in our example, the blockchain was located on the main node but once the second node gained access we suddenly saw that the blockchain was now reproduced on that machine.

Connecting to a Blockchain

Connecting to the blockchain is as easy as typing in a few commands on the terminal and possibly granting access from the main node. As discussed earlier, we need to only have access to the network that the host machine is on and not necessarily have an SSH or other explicit connection between the two machines.

Using the Blockchain

We have discussed the various uses of blockchain, the uses that are already well supported with MultiChain are assets, transactions, and general data storage. In our example we only showed general data storage where a node sets up a stream and both of them can write to the stream. Assets and transaction operations are very similar to data stream operations: with assets you need to first create the assets (initiate a stream), then you can write it to another node’s wallet which decreases it the sending node’s wallet. With transactions there is an option to also send hexadecimal metadata with the asset.

Other Features

There is a plethora of other features available with MultiChain. All versions since 0.10 support all commands with the Bitcoin Core API with the exception of the “accounts” mechanism; in most cases using a blank “account” will work. There is also an extension of the decentralization theme of blockchain to the administration component of MultiChain by the way of proportional consensus for administrators to modify their own permissions. Atomic exchanges are also possible in MultiChain allowing for reliable asset transactions. There is capability for making streams confidential using RSA to distribute public keys and AES to encrypt data. There is also a means of external key management to protect the keys that relate to node addresses used when digitally signing transactions[26].

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26. *No Author listed,* [*https://www.multichain.com/*](https://www.multichain.com/)*, various articles.*

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