Cloud Storage. A comparison between centralized solutions versus decentralized cloud storage solutions using Blockchain technology

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Abstract—**The introduction of Renewable Energy Sources (RES) have caused a series of challenges from an engineering perspective mostly due to their unpredictable nature. In order to consolidate, improve production of energy, transmission and distribution, the traditional power system has evolved from a monolithic architecture to a decentralized architecture. It's not uncommon for Decentralized Control Systems also known as Distributed Control Systems (DCS) to process data locally close to the area where it's generated using edge computing. This paper aims to study Blockchain technology, the advantages and disadvantages of implementing a decentralized solution using Blockchain in an increasingly evolving Cloud and IOT markets.**

***Index Terms*—Blockchain Technology, Cloud computing, Decentralized Data Storage, Smart Grid.**

I. INTRODUCTION

The term "Blockchain" was conceptually introduced starting with the year 1991 by Stuart Haber and W. Scott Stornetta "How to Time-Stamp a Digital Document" published in the Journal of Cryptology, which described the concept of blocks chained together and secured with encryption. In 1992 Merkle Trees added the possibility for the blocks to contain multiple records, introduced by Dave Bayer.

Blockchain technology implementation was started by Bitcoin in 2009 with public ***version 1.0***. During 2013-2014 the second version of blockchain was introduced, ***version 2.0*** starting with Ethereum in 2015 and smart contracts.

The third version of the blockchain technology is the public ***version 3.0*** and has been adopted by a multitude of industries building their own solutions.

II. BLOCKCHAIN STRUCTURE

Blockchain contains a series of transactions organized logically inside a block, these blocks are tied together using encryption in order to form a chain.

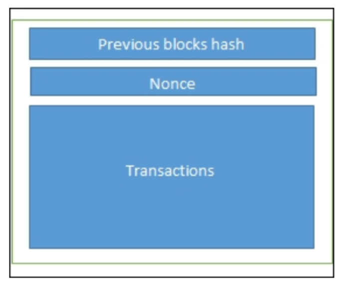

Fig.1 Block structure [2]

The technology itself allows peers to come to an agreement regarding the state of the transaction forming a decentralized consensus.

Conventionally the information is stored on private databases maintained by each organization. Database technology is commonly described by the CAP theorem and it refers to Consistency(C), Availability(A) and Partition Tolerance (P). No database can embody all three properties simultaneously no matter if the database is SQL or Non-SQL. In the case of Blockchain data is structured using a linked list that uses hash pointers instead of normal pointers.

Transactions are of variable sizes and include a reference of the previous block unless it is a genesis block. The genesis block is the first block in the blockchain hardcoded at the time the Blockchain was started and its structure differs depending on what type of blockchain technology is used.

In order to add blocks to the blockchain addresses are needed**. Addresses** are derived from a public key. These are unique identifiers that denote the sender and the recipient. The sender (a node for instance) makes a **transaction,**

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digitally signing it with its private key in order to transfer a value from one address to another.
Next the transaction is propagated through the blockchain network using Gossip protocol to peers in order to validate it. For transaction validation more than one node is required and once the validated transaction is included in the block, it gets propagated onto the network.
The newly created **block** containing multiple transactions, previous block hash, timestamp and nonce is added to the chain. Information is exchanged over a **peer-to-peer network** topology.
Using a **scripting and programming language,** transactions scripts are written to be used by **nodes** to perform various other functions.
Virtual Machines represent an extension of the transaction in order to extend its operation, for example **Ethereum Virtual Machine** (EVM) and **Chain Virtual Machine** (CVM).
State machine modifies the state of the blockchain to its final form as transactions are executed and validated by nodes.
Nodes give a Proof of Work (PoW) in the validation process of the transaction.
Smart Contracts are used to encapsulate the business logic and add additional flexibility to the blockchain and extra security Fig. 2.

III. CONTROL SYSTEMS USED IN ELECTRICAL POWER GRIDS

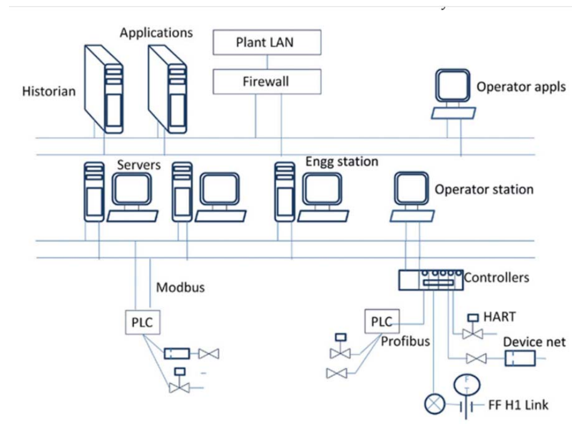

Fig 4. DCS architecture [6]

Automatic control systems have evolved from a centralized architecture, where a single element of control was present to manage the process without the intervention of the human operator, to a distributed architecture.
Distributed Control Systems (DCS) represent an assembly of processes or group of machines that are controlled by a dedicated controller. The elements of control used are Programmable Logical Controllers (PLC), microcontrollers, microprocessors, installed locally in various sections of a plant and are connected to the field devices such as sensors and actuators, using field bus protocols (Profibus, HART, MODBUS, etc.).
Distributed Control Systems are managed from the Engineering Station using software for analog/digital control to configure devices and it represents the place where control logic is developed combined with data processing and control algorithms.
Mounted near the field devices the distributed control units communicate with the engineering station in order to receive control instructions and parameters. The field devices

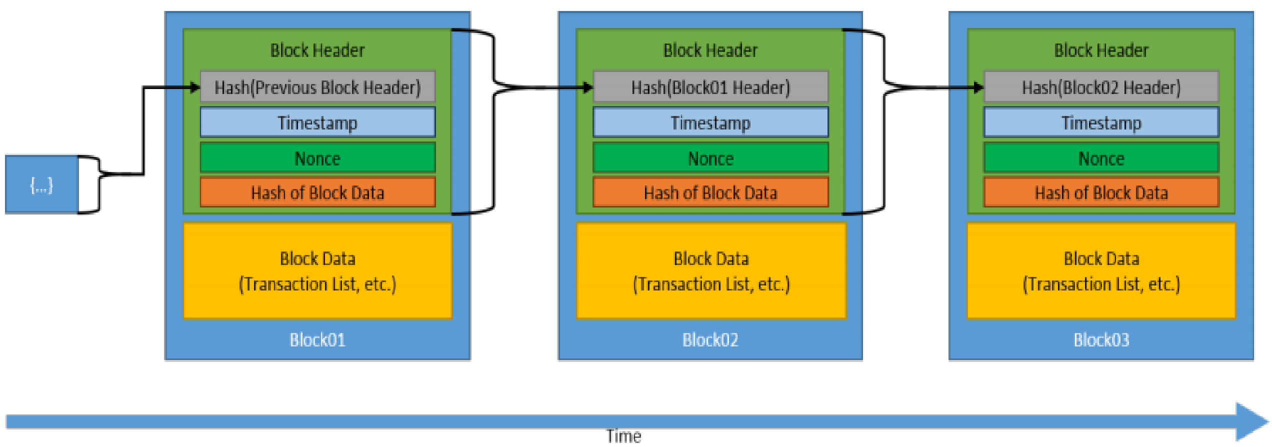

Fig 2 Blockchain Generic structure [7]

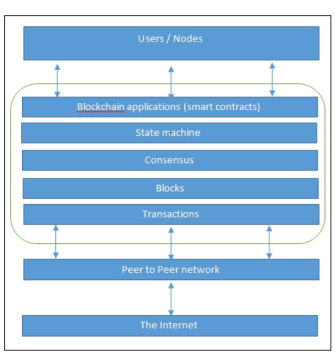

Fig 3 Blockchain-network view [2]

(sensors, actuators) are directly controlled by the distributed control units.

For performance evaluation and monitoring of the field devices of the plant an operating station or **human machine interface (HMI) is needed**. HMI contains a graphical representation of different functionalities, alarms, and real time values received from the field devices. Protocols used for data transmission are RS232 and Profibus using different communication media such as copper wires, fiber optics, coaxial cables including wireless communication.

The single point of failure has been eliminated in a DCS architecture thus preventing the entire automation system to fail but have become increasingly complex due to the amount of control devices that make up the system.

Supervisory Control and Data Acquisition Systems (SCADA) are used to monitor processes extended over a large geographical area. Based on the geographical area controlled. SCADA systems are divided into SCADA DCS and SCADA EMS. Energy Management Systems (EMS) are complex systems usually implemented at a national level, inside the Central Dispatch Center.

EMS systems offer a series of tools to help the central dispatcher make informed decisions such as:

- Automatic Generation Control (AGC);
- Real Time Contingency Analysis (RTCA);
- State Estimator (SE);
- Economic Dispatcher;
- Energy forecasting;
- Balancing Market;
- Short circuit current calculations;

A general characteristic of SCADA systems is that they are data-gathering oriented as opposed to DCS systems which are process oriented [17]. DCS systems play an important part in the SCADA system architecture performing regular scans of the process controlled and displaying results to the operator. In return SCADA maintains a database to log the values obtained from DCS and based on the values obtained the SCADA system performs certain actions.

The Smart Energy Grid is defined as a series of advancements with the purpose of solving specific issues concerning the energy sector. Advances in mobile technology allowed for the development of highly performant gadgets capable of merging consumer data and services throughout the Telecommunications infrastructure due to cheap and powerful processors. Advancements in RFID (Radio Frequency Identification) and COTS (Commercial Off-The-Shelf) components together with FOSH (Free Open Source Hardware) represent the promoters of IoT (Internet of Things) and I-IoT (Industrial Internet of Things) fields.

Blockchain technology aims to introduce the following features for future Smart Grid infrastructure:

- Decentralization

In order to help financial transactions, by using a distributed data storage mechanism Blockchain eliminates the need verify both buyer and seller. Storing all of the transaction information in a central location leads to hazards such as disclosure of user privacy and data tampering. All the nodes inside the blockchain network verify the information using a consensus mechanism and it's replicated on each node.

- Distributed storage

Geographically distributed nodes provide data storage for users and institutions. With the addition of a new block, the data contained inside it is verified by all nodes, inserted into the ledger and synchronized among all nodes.

- Smart contracts

In order to build a trusted network, different algorithms are used such as Proof of Work (PoW) and Proof of Stake (PoS).

- Encryption

Asymmetric encryption is provided such as SHA256 in the case of Ethereum Swarm.

IV. STUDY CASE – CONFIGURING A CLOUD STORAGE SOLUTION AND COMPARISON TO A DECENTRALISED CLOUD STORAGE SOLUTION BASED ON BLOCKCHAIN

Using a sensor connected to a Raspberry pi, data is generated and stored in a MySQL database. The database is located on the hard-drive of the PC which acts as local storage. The next step is to perform a backup of the database using a cloud storage solution. Amazon Web Services (AWS) is a cloud-based platform which offers the option to use S3 Bucket storage solution.

The configuration of Amazon's S3 Bucket for storing data was done following the steps described in the official documentation provided by AWS [8].

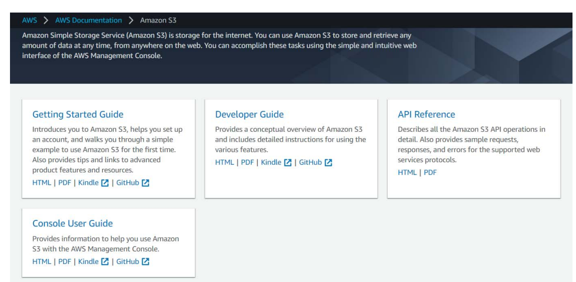

Fig.5 Amazon S3 Dashboard [8]

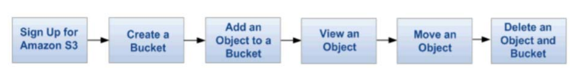

Fig. 6 Configuration steps S3 [8]

In order to perform backup using a Decentralized Cloud Storage solution the following options were taken into consideration:

- Storj
- Sia
- FileCoin
- Ethereum Swarm
- IPFS

Ethereum Swarm is a decentralized cloud storage system that is currently under development and offers integration

possibilities based on a series of interfaces and APIs provided and documented on the official swarm site [9].
Application Programming Interfaces (APIs) offer extended functionality using the HTTP verbs (GET, PUT, POST DELETE etc.)

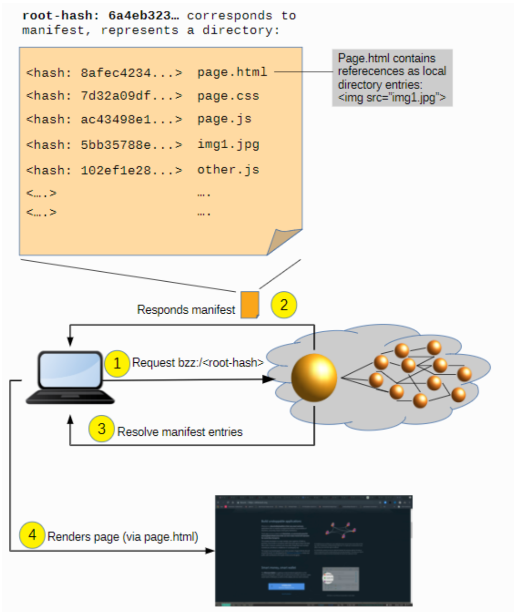

Fig. 7 Swarm arhitecture [9]

Ethereum Swarm components and notions [10]:

- **Swarm Hash** - used for storage and retrieval based on Merkle tree. *A Reference* represents the cryptographic hash that allows clients to retrieve and access the content in the case of unencrypted files.

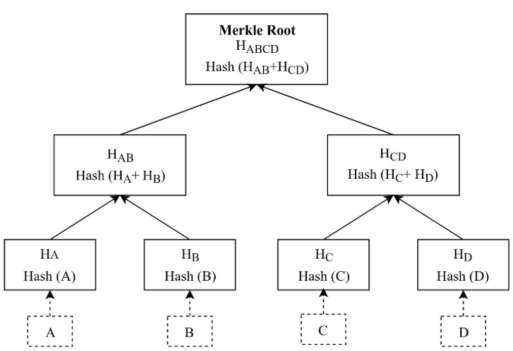

Fig. 8 Merkle tree architecture [12]

- **Chunker -** interface responsible for disassembling and assembling larger data. *Chunks* are pieces of data limited in size (4096 bytes) which are distributed inside the Ethereum network.
- **Web3 services and manifests.** A *manifest* is a data structure that describes file collections, paths to the corresponding content hashes used for URL based content retrieval.

The installation of Ethereum Swarm is done from sources on a machine with CentOS 7 operating system that has Gnome Desktop installed.
The prerequisites for this installations are:

- Go - installed with *yum install golang;*
- Git - installed with *yum install git*;
- Configuration of the Go environment:

$ mkdir $HOME/go
$ echo 'export GOPATH=$HOME/go' >> ~/.bashrc
$ echo 'export PATH=$GOPATH/bin:$PATH' >> ~/.bashrc
$ source ~/.bashrc

- Compiling and installing Swarm:

$ git clone https://github.com/ethersphere/swarm
$ cd swarm
$ make swarm

- In order to use Swarm an account is needed:

$ geth account new

V. CONCLUSIONS

Central cloud storage solutions introduce a single point of failure. In the case of Amazon S3 Bucket the data coming from an IoT device is stored on Amazon's Servers. If the S3 Bucket suffers a security breach the data stored is compromised. The technical solution presented has limited storage capacity as opposed to the Ethereum Swarm solution.
Another advantage of the Ethereum based storage is the encryption capability at the data file level using SHA256 asymmetric encryption method, the data inside the blockchain network cannot be altered. Ethereum Swarm **is a solution under development and it is not suitable for production purposes** but it represents a building block for the Ethereum blockchain vision together with Contracts to form a decentralized logic, Swarm decentralized storage and Whisper decentralized messaging [10].

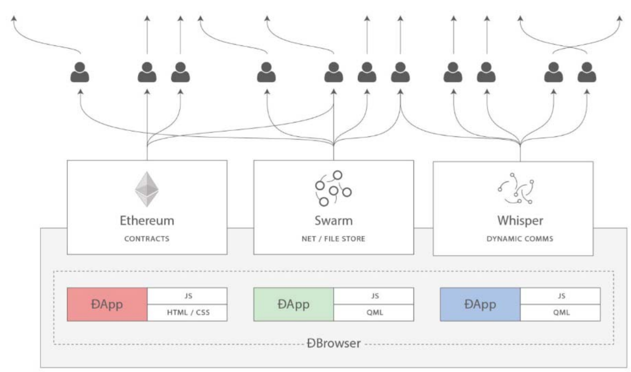

Fig. 9 – Ethereum view of the fully decentralized web [11]

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