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The role of Block-Chain in Cloud-based IoT solutions to build end-to-end automated and secured solutions

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Abstract - - Block-Chain is referred as the list of transactions stored in multiple participating servers rather than on a central transaction server. Each and every participant in the Block-Chain network is granted access to an up-to-date copy of this encrypted catalog so they can read, write, and validate transactions. Block-Chains have recently gained a lot of attention in IoT solutions even though they are used mostly in the financial domain. Block-Chain can relatively support in accomplishing the vision of distributed IoT, facilitating transactions and coordination among interacting devices. The two technologies Block-Chain and IoT are used to build end to end automated and secured solutions. Internets of things (IoT) solutions are being effectively implemented in many different sectors, such as healthcare, warehousing, transportation, and logistics. Current unified, Cloud-based IoT solutions may not gauge and meet the network security defies faced by large-scale enterprises. The use of Block-Chain as a distributed catalog of transactions and peer-to-peer communication among contributing nodes can unravel such problems. This paper gives an idea of Block-Chain-enabled IoT solutions and shows how to use the Block-Chain platform for an IoT application in a multi partner environment.

Keywords- Cloud-based IoT; Network security; Block-Chain Services; Application Programming Interface; Messaging Protocol.

I. INTRODUCTION

1) IoT and the Cloud IoT Platform

IoT has brought together enormous chances for businesses and consumers, particularly in the areas of healthcare, warehousing, transportation, and logistics. IoT solutions involve a difficult network of smart devices, and IoT provides the chance to develop novel services based on cloud-enabled connected physical devices from machines and cars to home utilizations.There are three key tiers of Cloud-supported IoT solutions, each with particular accountabilities.

Devices / gateway: These are shrewd devices or sensors that gather data about the corporal world, such as the temperature of a refrigerated container conveying fresh foods, or health data for a patient who's admitted to the hospital. Devices are connected to the internet to transfer this data securely to an IoT platform for examination, processing, and actions based on that data.

Cloud IoT Platform: Cloud IoT Platform gathers data from IoT devices and provides various services that examine the data and take subsequent actions to unravel specific business problems [2] [8]. The Watson IoT Platform offers a rich set of intellectual services such as machine learning, machine reasoning, natural language processing, and image analysis that improve the capability to process the unstructured data composed from the various intelligent sensors.

Cloud IoT Platform is an open standard based cloud platform for structuring, running, and managing applications and services [13] [25] [28]. Including analytical and reasoning abilities helps IoT applications by making it serene in those applications based on numerous runtimes and amenities.

2). Block-Chain and IoT

While IoT employment is growing considerably, some key challenges need to be addressed to make IoT solutions to measure and support the nonstop claim for more and more connected devices. IoT solutions must elucidate the network security and privacy apprehensions around these devices and the data they gather [1] [5]. Some of these defies are:

- **Scalability:** Recent integrated, cloud based IoT platforms impose message routing through these platforms [18] [29]. This implementation creates a blockage to scaling the IoT solutions to much number of devices.
- **Security:** The huge volume of data that's composed from millions of devices upsurges information security and privacy apprehensions for individuals, corporations, and governments [27]. As confirmed by recent denial-of-service attacks on IoT devices, the huge number of low-cost devices connected to the internet is evidencing to be a major defy in confirming IoT network security.
- **Lack of data standards / uniformity:** The world is rotating towards open data creativities, but there is no consistent approach. There are numerous protocols but there is no single platform for linking devices from all manufacturers [3] [9]. The interoperability of devices and platforms is a key defy to the progress of IoT solutions.
- **Cost** IoT solutions are related with a huge number of devices and their network tools. The costs related with IoT solutions are signifying to be very high as they need to supply to a very high volume of messages (communication costs), data produced by the devices (storage costs), and analytical processes (server costs) [15]. Consequent growth will only increase to these costs.
- **Architecture:** Centralized cloud platform persist a bottleneck in end-to-end IoT solutions. Any disturbance there can affect the entire network.

II. RELATED WORKS

1. Decentralized IoT Networks

Block-Chain technology and IoT provide a new world of assurance, and can be leveraged to address the issues described overhead. Distributed IoT networks built using open standards can elucidate many of the difficulties related with today's integrated, Cloud-based IoT solutions, including network security, scalability, and budget [6] [34]. For example, connected devices could communicate directly with distributed catalogs. Networks built using Open standards could then be used by smart contracts to modernize and authenticate the data and consequently deliver it to all intent contributors in the business network. Human monitoring and actions will be reduced, and promote trust in the data generated by the devices [21] [22] [23]. Executing predefined smart contracts and employing explicit consensus mechanisms considerably eliminate actions from compromised devices which improvises the network security of IoT; that can be achieved using decentralized Block-Chain networks.

The Cloud IoT Platform now supports the use of Block-Chain services for IoT applications. Data from IoT devices can now be combined with the private Block-Chain catalogs and shared transactions with high security [13] [17]. The Block-Chain's spread duplication mechanism removes the need to have all IoT data composed and stored centrally, and permits the use of the IoT data in a distributed way.

2. IoT USE CASES USING BLOCK-CHAIN

In the asset management cycle the combination of IoT and Block-Chain is producing a lot of novel possibilities for using smart devices [10] [23] [30]. In their different phases of the assets life cycle in order to provide real time trusted data to the participants monitoring various scenarios by the devices and integrating the data from them into a Block-Chain of the business participants is done With Block-Chain's smart contracts, protocols can be produced to observe and govern the temperature of a building based on the utilization of energy and value information of the energy from suppliers partaking in the network.

Similarly, the eminence and cost of the food items can be dogged based on the instantaneous refrigeration data used in transportation. Producers such as Samsung demonstrated the use of Block-Chain in autonomous washing machines that can rearrange cleanser and spare parts, and organize for after-sales service using clever covenants.

Various groups such as chain of things and recent companies such as filament have revealed other smart ways of leveraging distributed catalogs in IoT networks to computerize the end-to-end processes and amalgamation with business participants [35].

3. IoT use cases for different industries based on Block-Chain

a) Supply chain

In the supply chain lack of visibility is a significant issue. Even when data on the processes exists it's not reliable enough that it should initiate tangible actions. Block-Chain can be used to solve some of the major problems in the supply chain: visibility, optimization, and demand. It can guarantee appropriate access control for data shared among participants in the supply chain. When compared to conventional supply chains a supply chain with uninterrupted, real-time access to reliable, shared data in Block-Chain can be optimized more proficiently than that of traditional supply chains.

Tangible supply chain use cases based on Block-Chain and IoT include:

- Monitoring food items from farm to wrapping and transport
- Identifying adulteration and decreasing food waste in the supply chain

These use cases take into consideration the location, refrigeration, soil, and weather data streams in an IoT Block-Chain to make all appropriate data accessible to contributors in real time [39].

b) Automotive

The automotive industry is one of the foremost industries in the acceptance of Block-Chain based IoT solutions. The solutions based on Block-Chain are being used to deliver real time information and to perform transactions among major business partner's producers, service providers, auto financing companies, insurers, regulators, and customers. Apart from the acceptance of Block-Chain in auto supply chains, sensor data from several vehicle parts are combined with Block-Chain to make real time decisions and transactions containing services and payments [11] [12] [37]. For instance many car manufacturers track the thousands of parts that travel through various countries, factories, and suppliers, to manufacture a single car by using Block-Chains [41].

c) Energy and utilities

Block-Chain has disruptive potential for the energy industry. IoT networks supported by Block-Chain of energy grids allow peer-to-peer transactions of energy.The surplus rooftop solar energy is sold to other users who need it; for which they have to pay and logged through a Block-Chain [38]. To monitor energy grids and fix any issues that arise as quickly as possible companies like Filament are also building mesh networks of smart devices.

d) Healthcare

It helps to improve the network security of private patient data received from medical monitoring devices [4] [7]. In a distributed register data is stored securely and participants are given access based on smart access rules that are set in the Block-Chain for instance, approval from 3 or more parties.

It also helps to provide real time trusted patient data for required participants such as insurance providers or third-party administrators and assists them release payments based on more accurate data [36].

e) Home automation

In smart cities and buildings IoT-enabled technologies are being used to improve network security, operations and the comfort of residents [16] [19]. Also to monitor and manage these facilities large number of devices and sensors are being used.

A Block-Chain-enabled IoT network can protect devices and the data composed from them. All facility management providers can contribute in a private Block-Chain to offer timely service and automate the payment process based on the actual work done or the quality of service.

f) Other industries / applications

The management of devices and the security of the data flow in the network can be improvised by the IoT technology. It allows a) the access control of the data that flows to different participants b) the exchange of data midst participants, and provides the necessary payment services that are integrated with the flow of the data [36].

III.ARCHITECTURE OF BLOCK-CHAIN IOT APPLICATIONS

1. Representational State Transfer REST/RESTFUL API

It is one of the most popular types of API (Application Programmable Interface); it is designed to take benefit of present protocols. It can be used over readily on any protocol, also when it is used for web APIs it typically takes the advantage of Hyper Text Transfer Protocol i.e. when creating a REST API there is no need for the developers to install additional software or libraries.

REST API- Using the HTTP Interface the Block-Chain REST API helps to act together with the Block-Chain peers. The great deal of flexibility is key advantages of REST APIs. Data is not bounded to resource/methods, so it can handle multiple types of calls that returns different data formats and also change structurally with the correct employment of hypermedia. This feature of REST/RESTFUL API allows developers to build an API that not only serve their needs but also the needs of very diverse customers.

2. Data from devices are sent to IoT Platform using MQTT

MQTT stands for MQ Telemetry Transport. It is an extremely simple and lightweight messaging protocol that is designed for controlled devices and low-bandwidth, high-latency or unreliable networks. The design principles of MQTT minimize network bandwidth and device resource requirements that also attempts to guarantee reliability and some degree of assertion of delivery. These principles of MQTT make the protocol ideal of the emerging M2M - machine-to-machine or IoT-Internet of Things sphere of connected devices, and mobile applications in which the bandwidth and battery power are at a premium level. The proxy Block-Chain in the IoT Platform based on a pre-defined configuration sends the data to the sequence code. In the cloud based on the device data the Smart transactions are executed.

Table1. Methods and Procedures

A list of methods and its procedures is shown in the table below:

S.No	Method	Procedure	Description
1	GET	/chain/blocks/{Block}	Within the Block-Chain it returns information about a specific block
2	GET	/chain	Information about the current state of the Block-Chain is returned
3	POST	/chaincode	Requests to install, rise and question a target chaincode is received by the /chaincode endpoint
4	GET	/network/peers	Current network connections list for all the target peer node is returned by API which includes both validating and non-validating peers is achieved using this method.
5	POST	/registrar	Used to Register a user with the license authority
6	DELETE	/registrar/{enrollmentID}	From the local repository it deletes any existing client login tokens. The intended user will not be able to execute transactions after the accomplishment of this request.
7	GET	/registrar/{enrollmentID}	Confirmation of the specified user with the certificate authority is provided.
8	GET	/registrar/{enrollmentID} /ecert	The enrollment certificate for a given user which has been registered with the certificate authority is retrieved using this method.
9	GET	/registrar/{enrollmentID} /tcert	It recovers transaction certificates for a given user who had registered with the certificate authority
10	GET	/transactions/UUID	The transaction matching the specified UUID is returned at this endpoint

IV. RESULTS AND DISCUSSION

1. Solution Components Of Block-Chain Services

Block-Chain Service

The Block-Chain offers the private Block-Chain structure for developing Block-Chain-enabled solutions. It is an implementation of Hyper Catalog Fabric.

It offers Block-Chain network comprising of 4 peers:

- An authority for certification verification
- Smart agreement chaincode (chaincode, developed via Golang)
- The world / registry state, which contains the current value of smart contract data.
- The history of entire transactions is also available in the Block-Chain

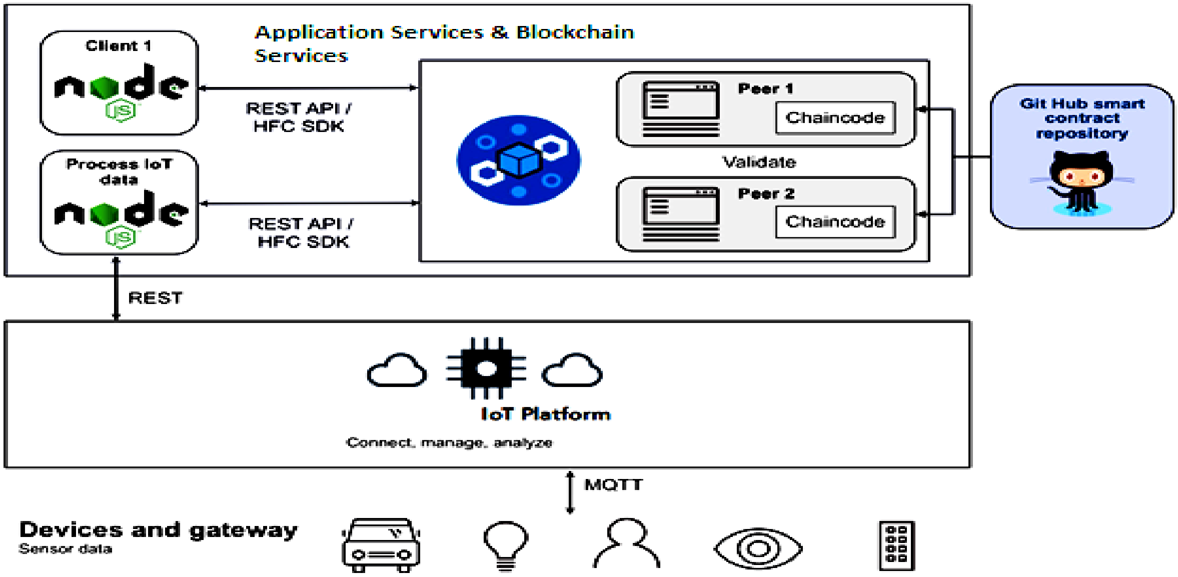


Fig. 1.BlockChainIoT application architecture

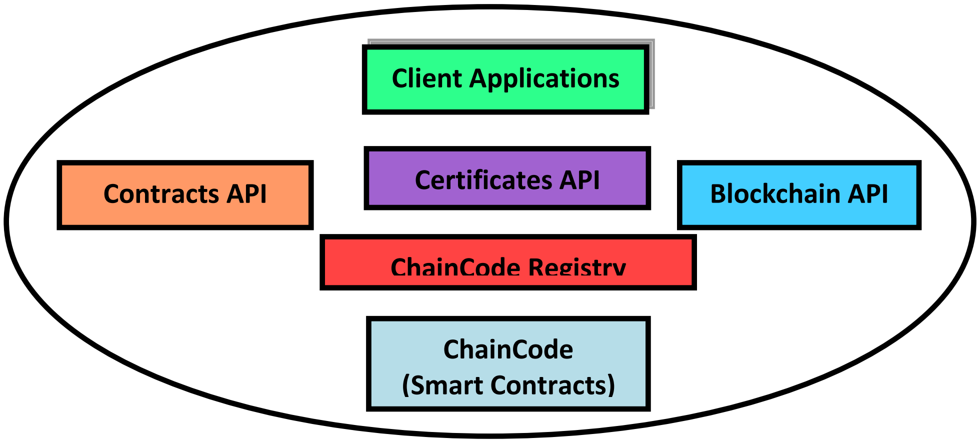


Fig.2. Subcomponents of Block-Chain services

Component 1: Smart contracts

It is the core of Block-Chain transactions and it encapsulates the business logic. Every invocation of a smart contract is noted as a Block-Chain transaction. Go language is used to develop Block-Chain contracts and need to implement the Contracts API.

The Smart contracts must be registered with Block-Chain services through pre-defined APIs.

Component 2: Contract API

A smart contract developer is used to implement contract API that includes three main functions a) Init() b) Invoke(), and c) Query().

Component 3: BlockChain API

It is the client API for Block Chain applications. The application developers build Node.js applications using Hyper catalog Fabric Client (HFC) Software Development Kit that enables interaction with a Block Chain network. The users of the applications can securely registered and submit their transactions with the help of this API.

2. Developing Block-Chain IoT applications

Figure 3 shows the steps involved in developing a Block-Chain-enabled IoT application using the IoT Platform and Block-Chain services. Using these services skilled developers are needed to develop end-to-end IoT applications. Figure 3 shows the steps involved in developing a Block-Chain-enabled IoT application using the IoT Platform and Block-Chain services. Using these services skilled developers are needed to develop end-to-end IoT applications.

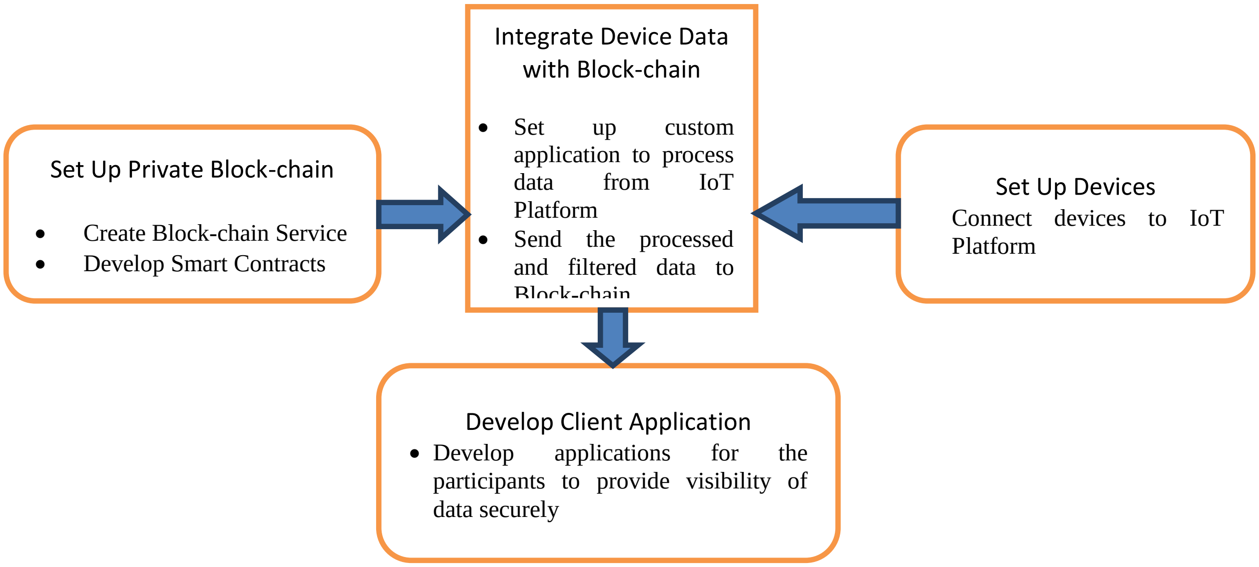

Set Up Private Block-chain
• Create Block-chain Service
• Develop Smart Contracts
Integrate Device Data with Block-chain
• Set up custom application to process data from IoT Platform
• Send the processed and filtered data to Block-chain
Set Up Devices
Connect devices to IoT Platform
Develop Client Application
• Develop applications for the participants to provide visibility of data securely

Fig. 3. Developing Block-Chain IoT applications

There are numerous alternatives to developing client applications for Block-Chain:

a) **Block-Chain-js:** Block-Chain-js is a Node.js covering library over the RESTFUL API that's provided by Block-Chain services. It provides operations in the user friendly Node.js API that are alike to those available in the RESTFUL API.

b) **HFC SDK:** The Hyper catalog Fabric Client (HFC) SDK for Node java script is a gRPC based Application Programmable Interface that offers a user friendly interface for developing applications based on the Block-Chain service. The HFC is designed to be used in the Node java script JavaScript runtime.

c) **The client application:** The client application is accountable for giving the required data to shareholders to meet their business demands and give them a rich user experience. The Block-Chain API is used by the client applications as provided for the smart contracts to interoperate with the business catalog. These applications can manipulate the events produced by the Block-Chain components.

d) **IoT Platform:** The IoT Platform obtains data from the registered devices and manipulates that data into the format demanded for amalgamation with Block-Chain. The Block-Chain contract developer not necessary to know the details about the source of the data, and they can concentrate on developing the contract logic.

3. Overview of Each Step In The Process:

1**. Private Block-Chain Infrastructure Set Up:**

Based on the Block-Chain service the developers need to set up a private Block-Chain. Also based on the device data the developers deploy smart contracts in Block-Chain. If the temperature of the container which is measured by sensors exceeds a certain threshold a contract can be set up in order to reject a shipment or reduce a price.

2. **Connecting Devices to the IoT Platform**

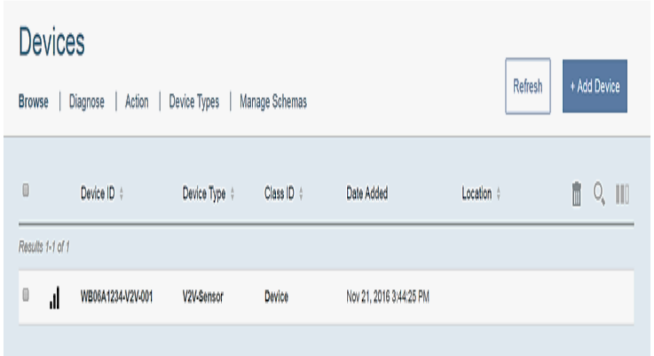
The sensors / gateway is connected to the IoT Platform which enables the devices to send data to filter or aggregate and successively send to the Block-Chain. After successfully added, the Devices page on the IoT dashboard will be as below:

3**. Device Data Integration with the Block-chain Distributed Catalog**

The incoming raw data or filtered/analyzed data need to be sent to the Block-Chain service running in Cloud once the device data is received. Using the HFC REST API Block-Chain smart contracts can be triggered from the Node-AGG/FLT workflow. This Node-AGG/FLT can also be used to aggregate and/or filter device events and to initiate the smart contracts with the necessary parameters.

4**. Developing End Users Client Applications**

Making the transaction outputs or events available for the end users is the final step. Client application can be developed, using the Block-Chain API a client application can be developed and other analytical services using multiple languages / platforms supported by Cloud.



□	Device ID	Device Type	Class ID	Date Added	Location
Results 1-1 of 1					
□	WB06A1234-V2V-001	V2V-Sensor	Device	Nov 21, 2016 3:44:25 PM	

Fig. 4.IoT dashboard Devices page

V. CONCLUSION

There is enormous potential for application development using Block-Chain in IoT solutions, and this blend can solve issues such as security and scalability which are some of the important problems that restrict the adoption of IoT. We have explored architectures of IoT based block-chain applications which provides an idea of using block-chain technology in an IoT platform on a multiple partners environment. Multiple partners' processes can be completely automated using distributed catalog with implanted smart contracts which also improves security and trust. This IoT Platform can be pooled with Cloud-based Block-Chain services to provide an instant deploy platform for Block-Chain-based and open-standards-based IoT applications. Still few challenges are to be overcome. We are specifically keen about constructing systems for multi-media objects using IoT; however it has received notably less scrutiny inside the advice networks. Multi-media objects, including images and motion pictures, incorporate a good deal richer visual semantics that could replicate customers' interest. To construct an IOT based multi-media system, we want to develop effective methods to study from multi-view and multi-modal data. Another emerging course is to explore the capability of recurrent block chain and IoT techniques for providing efficient online advice. Firstly the major challenges of Block-Chain based IoT applications is the restricted computing potential of many IoT devices. Secondly encryption and verification of Block-Chain transactions can demand substantial processing power, which may not be available in low-end devices. The energy consumption and the cost of the solution both can be altered finally.

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