JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

BLOCKCHAIN FOR WASTE MANAGEMENT IN SMART CITIES

[1]Yuvraj Jeughale, [2]Vidya.D. Argade, [3]Pratik Ghadge, [5]Saurabh Kale

[1]Student, [2] Professor, [3] Student, [4]Student
[1] Department of Information Technology,
[1]Dhole Patil College of Engineering, Pune, India,

Abstract : The combination between innovative motifs and arising technologies lets experimenters define new processes and models. New needs regard the description of modular and scalable approaches, with society and terrain in mind. An important content to concentrate on is the smart megacity one. The use of arising technologies lets smart metropolises develop new processes to ameliorate services offered from colorful actors, either diligence or government. Smart metropolises were born to ameliorate quality of life for citizens. To reach this thing, colorful approaches have been proposed, but they warrant on a common interface to let each stakeholder communicate in a simple and fast way. This paper shows the offer of an armature to overcome the factual limitations of smart metropolises it uses Blockchain technology as a distributed database to let everyone join the network and feel part of a community. Blockchain can ameliorate processes development for smart metropolises. Scalability is granted thanks to a environment- apprehensive approach operations don't need to know about the reverse- end perpetration, they just need to acclimatize to an interface. With Blockchain, it's possible to collect data anonymously to make some statistical analysis, to pierce public records to insure security in the megacity and to guarantee the origin of products and energy.

IndexTerms - Blockchain, Data Analytics, West Management, Security, Smart Cities.

I. INTRODUCTION

The rise of arising technologies defines new and im- proved software processes. The modelling of an armature is the first step to acclimatize a process grounded on specific requirements defined by functional and non functional conditions. It's necessary to design some innovative approaches during the description of the armature to produce a solid and scalable system. Among colourful innovative motifs in Software Engineering, we concentrate on smart metropolises enhancement. The smart megacity trend is constantly growing as new and arising technologies help its spreading. A smart megacity thing is perfecting the quality of life for citizens, as well as making operations easier and more effective. To make a smart megacity desirable, the network should be dependable and with high performances; also, sequestration and encryption of data should be guaranteed and the conception of trust should be a solid foundation of the entire process.

A typical problem in smart metropolises development is modularity new operations must be contextualized and developed having that smart megacity in mind. Actually, there are no norms and guidelines that can acclimatize to every smart megacity.
Our offer is grounded on the use of Blockchain technology to ameliorate our capability to develop, manage and apply new software and system operations for smart metropolises. To illustrate the main end of this paper, let us consider a sample script suppose we'd develop a system that provides smart megacity services, using a single distributed database enabled for penetrating megacity- related information for citizens. Traditional metropolises can come smart without using new systems, but simply uniting with being bones and with distributed databases used by other smart metropolises. Hence, as shown in Fig. 1, a smart megacity actor must have a single interface to gather different data and to use the database; this means that the interface and the perpetration of an object can vary singly being separated from one another. The perpetration can be realized just formerly and be biddable to every other smart megacity that implements the proposed interface.

The paper is organized as follows Section II lists some characteristics of Blockchain technology and presents some state of the art analysis to understand what are the benefits and exploration directions on Blockchain applied to smart metropolises. Section III discusses the purpose of the paper. Section IV shows the offer of a scalable armature that connects each smart megacity actor to the Blockchain using a common interface, together with some considerations on different ap- plications of similar system. Eventually, Section V concludes the paper.

II. BLOCKCHAIN CHARACTERISTICS

Blockchain technology belongs to Distributed Ledger Technologies (DLTs): born in 2008 thanks to Satoshi Nakamoto [1] can be conceived as a distributed database where information are stored in blocks. Each block is connected to the previous and next

one thanks to cryptographic (hash) functions. The main Blockchain features are proposed below, to better understand its peculiarities.

- **Decentralization:** all transactions in a Blockchain are inserted and validated through a consensus protocol, then they are replicated between all the nodes participating in the network. In this way, there is no need of a central authority (i.e., a bank from the financial point of view) to maintain all the transactions data.

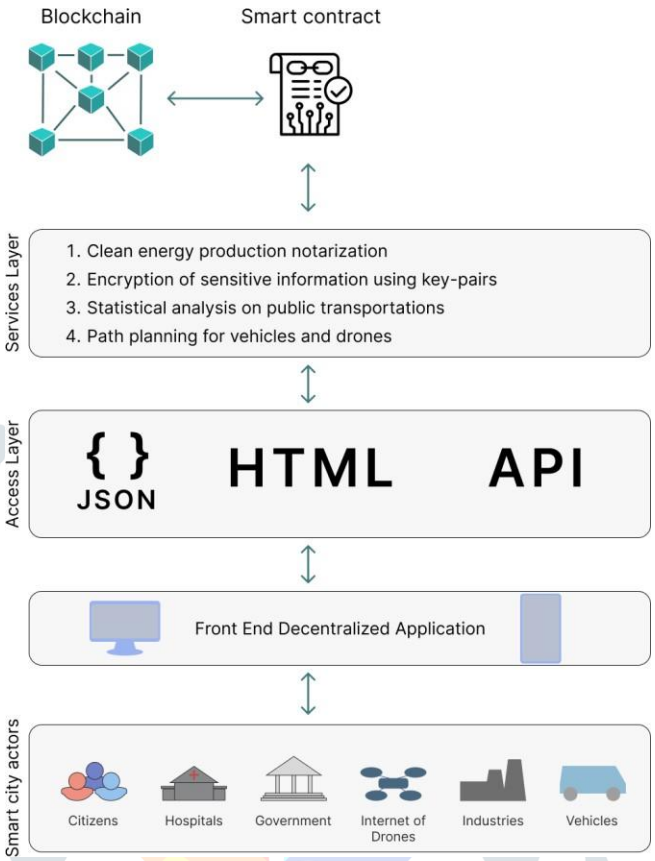

Fig. 1. Layers of the system showing a single interface in the access layer

- **Invariability** deals in a Blockchain are stored into blocks. Each block contains its hash and the hash of the former block, creating a chain that's inflexible, be- beget any change on a block will affect all the posterior blocks. An bushwhacker can not change the information of a block N without changing all the blocks N + 1, N + 2,., M, where M is the total number of blocks in the chain. This change is computationally delicate, so it isn't possible to execute it in a short quantum of time.
- **Translucency** the only way to modernize the tally is by reaching the agreement by utmost of the network bumps. All changes are intimately visible this ensures translucency and security.
- **Traceability** it becomes easy to trace all deals in a Blockchain thanks to its invariability and translucency features. In this way, every sale can be traced down back to its origin.
- **Trust-less** it's possible to make sale, in a Blockchain, between unknown parties, indeed if they don't trust each other. Thanks to the absence of a central authority, it's possible to trust the validity of a sale without knowing who was involved in it.

III. Literature Review

Different reviews show the part of Blockchain in smart metropolises, with some focus on smart healthcare, smart transportation, force chains(2). They also accentuate the combination of Blockchain and other technologies similar as Internet of effects and Machine literacy(3). Blockchain can help smart metropolises in being more sustainable thanks to its tricks a) it's inflexible, so every information added to the chain can not be modified, b) it's anonymous, meaning that everyone can join the network without fussing about sequestration, c) it's responsible indeed if people do n't know each other.

Authors of paper(4) concentrate their exploration on Blockchain smart contracts in smart real estate. They propose a abstract frame for the relinquishment of similar content in smart metropolises. The real estate process becomes further immersive and stoner-friendly, in line with Assiduity4.0 conditions.

Blockchain can help smart metropolises development(5) both from performance and security sides. The distributed nature of this technology makes infrastructures more scalable and with lower point of failures as soon as one knot is active, the entire network is over. Data participating takes advantage of this approach education, healthcare, structures can communicate using a single common interface. Artificial Intelligence intervenes in data operation and analysis(6) deep literacy ways can enrich the green energy product(7),(8), while neural networks can ameliorate road operation(9).

Traceability specific of Blockchain is helpful for waste operation(10) thanks to inked attestation, compliance with laws and line operation. It's also useful with respect to public exigency services(11) it can help security workers to manage different anomalies, from fires to crimes. A state- of- the- art summary is shown in Table I. The analysis of similar publications raises some open challenges a) Sustain- capability is an important aspect in the content of Blockchain applied to smart metropolises. It's the farthest exploration content from utmost of the analyses(3). b) There's the need of a single interface to the Blockchain, to produce a ground between different actors in the smart megacity and a single, common distributed database. c) Security and sequestration should be underscored(12) Blockchain preserves sequestration and ensures that only authorized bumps can pierce sensitive information. d) Costs to emplace a complete Blockchain network in a smart megacity aren't yet known. It's delicate to perform a cost vaticination in the deployment of a Blockchain in a smart megacity(2). e) Regulations are demanded to rightly partake information smart contracts can come in hand in this content.

IV. Our Vision

We fantasize a script in which Blockchain is the foundation of smart metropolises processes. Each process can be fluently added to the system thanks to a common interface that embraces every aspect of the megacity. Information can be changed using JSON format, so the communication between a frontal end decentralized operation and the Blockchain is environment- apprehensive. Blockchain technology has the implicit to play an important part in the development of smart metropolises. It can give multiple advantages in numerous motifs

Paper	year	Topic
xie2019survey [2]	2019	Survey on the literature involving Blockchain technology applied to smart cities
rejeb2022blockchain [3]	2022	Trends and research directions for Blockchain applied to smart cities
ullah2021conceptual [4]	2021	Usage of smart contracts in smart real estate environment
shari2022state [5]	2022	Survey of Blockchain applications for data management in smart cities
sharma2021sustainable [6]	2021	Integration of Blockchain and Artificial Intelligence for sustainable smart cities
ahmad2021blockchain [10]	2021	Usage of Blockchain for waste management in smart cities
kumar2022best [11]	2022	Protection of life and properties from fire damage in smart cities using Blockchain
ghazal2022securing [12]	2022	Protection of smart cities using Blockchain as a distributed database

- Supply chain management: Blockchain can be used to track goods and materials through a supply chain, thus increasing transparency and reducing the risk of fraud.
- Sustainability: Blockchain can be used to manage and track the use of renewable energy. A sustainable smart city can be obtained if actors reduce their carbon footprint and promote green approaches.
- Authentication and identification: Blockchain can be used to verify identities in a secure and decentralized way, making it easier for citizens to access services and participate in civic life.
- Public records: Blockchain can be used to store and manage public records, such as property titles or licenses.
- Transportation: Blockchain can be used to manage and track the use of public transportation, helping cities optimize their transportation systems and reduce congestion. Transports side, Blockchain can be used to gather information to improve paths, waiting times and overall services.

Overall, the role of Blockchain in smart cities management is to improve different aspects, from sustainability (i.e., notermination of clean energy production) to hijacking avoidance (i.e., guaranteeing the path of a bus or a taxi, making statistical analysis for public transports, identifying passengers). The ultimate goal is to improve quality of life for citizens.

A. Clean energy production

Smart buildings must be energy efficient and incorporate clean energy production technologies. The ways to accomplish this goal are different: a) solar panels can be installed on the roof of a building to capture sunlight and generate electricity, b) wind turbines can convert wind speed to electricity, c) storage systems, such as batteries, can store excess clean energy produced during low demand times. Blockchain technology can support the production of clean energy in multiple ways:

a) it can track and verify the energy production, to ensure that a building is sustainable; b) it can help the trading of energy, notarizing transactions between a building with enough energy in its storage and a building with less energy than requested; c) it can help people understand if a building is really sustainable and green (i.e., showing a building carbon footprint), thus letting people choose and prefer smarter and more efficient buildings.

B. Encryption of sensitive information

Citizens side, information should be translated to insure sequestration and anonymity. The encryption process can be both symmetric or asymmetric. In this offer, we follow an asymmetric crucial encryption scheme, that takes advantage of the crucial-brace formerly present in every Blockchain armature. In this way, everyone can cipher any kind of communication using the philanthropist public key, therefore guaranteeing that only the philanthropist can decipher the communication using his or her own private key.

In the case of public services requests, it's possible to use smart contracts to make the process secure and transparent. The authentication and request process is shown in Fig. 2.

1) The citizen requests a service to the institution(i.e., a instrument of hearthstone). The request is managed by a smart contract. It's also possible to directly upload documents to the Inter Planetary train System(IPFS)(13), but due to lack of regulations and laws, we decided to let institutions keep sensitive documents.

2) The smart contract, together with the institution, authenticates the citizen and ensures that the requested instrument is accessible.

3) The smart contract requests the document to the institution.

4) The institution gives back the requested service using the same smart contract.

5) The citizen receives the requested service or document. The process, thanks to smart contracts intervention, is transparent, secure and fast.

C. Statistical analysis

The use of a distributed database such as Blockchain lets people read public records, that are stored in the chain and accessible to anyone. These data are stored anonymously, meaning that any information can be related to a public key (wallet), but there is no way to link that wallet to a person. In this way, data can be used to make some statistical analysis to understand how to improve services offered to citizens. Public transports can easily understand if there is a lack on the offer and improve it, knowing exactly where to act.

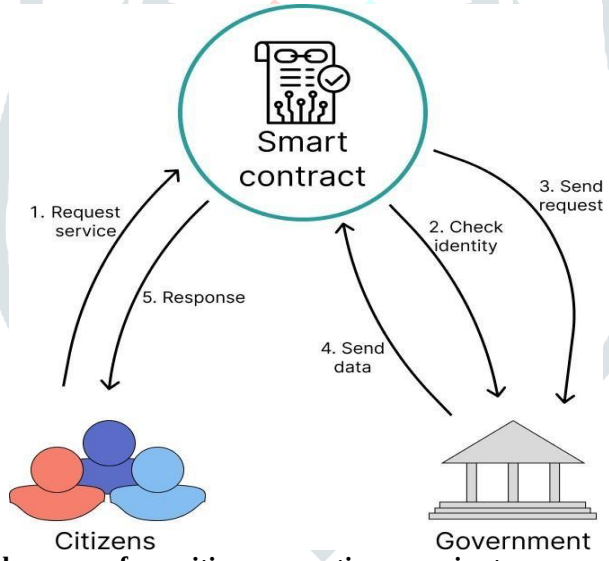

Fig. 2. Sample process for a citizen requesting a service to government institutions

D. Path planning

The process of determining one optimal route for a ve- hicle to travel from one position to another is defined as path planning. This approach can be used to avoid business traffic in smart metropolises(14) or to snappily intermediate in case of disasters(15). Path planning can be used for vehicles, drones and people. With Blockchain technology, it's possible to avoid kidnapping in the Internet of Drones(IoD) field, colorful approaches have been proposed(16) –(18). They all partake a common point of view everytime a drone approaches a new Point of Interest(PoI), it writes a new information on Blockchain to endorse its position. In this way, every attempt of kidnapping can be linked in short time. The same approach can be considered for Autonomous Guided Vehicles(AGVs) in a smart megacity AGVs can read from the Blockchain where they've to go, also they can produce an optimal path and endorse the time of appearance. These information can further be used for statistical analysis, as underscored ahead.

V. Proposed Architecture

Our donation regards the design of an armature where every actor in a smart megacity can profit from using Blockchain as a aft end of the system. The main thing is the development of a common interface to communicate with the database, so everyone can join the network in a secure and fast way. Smart contracts can admit any kind of data in a JSON format new actors just need to upload JSON- formatted information. Data are also managed by the contract, that gathers them and con- verts them into value, therefore uploading them in the Blockchain. An armature showing different actors is proposed inFig. 3.

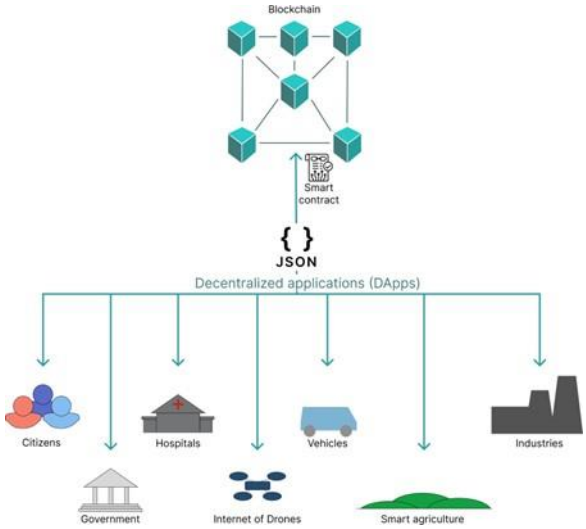

Fig. 3. Architecture of the proposed Blockchain-based smart city

In our script, each actor uses a Decentralized operation(DApp) to connect to the Blockchain. DApps are designed to be distributed and to run on multiple bumps, rather than being controlled by a single reality. Some operations of similar armature can be added up as follows

•A. Clean energy product. To reach sustainability purposes, clean energy product can be inked in Blockchain. Everyone can insure that the energy used in a structure comes from renewable sources.

•B. Encryption of sensitive information. Sensitive information can be translated using bumps crucial- brace. Autonomous participated vehicles(i.e., hacks) can use this sign to authenticate passengers and insure that only the passenger who payed for the lift can use that vehicle.

•C. Statistical analysis. Public transportation can make statistical analysis(i.e., preferred destination, staying times, etc.) to ameliorate the offer, still guaranteeing obscurity.

•D. Path planning. Path planning is possible to avoid kidnapping . In the Internet of Drones content, this can be

a useful approach to insure that the path followed by a drone is correct and there's no tampering(18),(19). either, every actor in the smart megacity can feel as part of a community, fluently penetrating any public information in the Blockchain and swapping dispatches with other actors in a transparent way.

The armature felicitations conditions for erecting a system process with modularity and scalability in mind, therefore icing high performances and trust ability that are guaranteed by the presence of Blockchain.

A prototype is being developed to show the advantages of espousing a single access subcaste. To upload JSON information to the Blockchain, some environment- apprehensive smart contracts are designed, as proposed in Fig. 4. These smart contracts take the input, make some checks on the correctness of data and also upload them to the Blockchain. Data are accessible by smart megacity actors; the reclamation process gives as affair a JSON object. The specific frontal end distributed operation can manage the JSON affair to show the information requested by the stoner. The described process is shown in Fig. 5 way from1.2 to1.3 are independent from the frontal end distributed operation.

```
async updateDocData(ctx, id, oldData, updatedData) {
    const old_data = JSON.parse(oldData);
    const updated_data = JSON.parse(updatedData);

    const updatedDoc = {
        ...old_data,
        ...updated_data,
    };

    await ctx.stub.putState(id, Buffer.from(JSON.stringify(updatedDoc)));
    console.log(updatedDoc);
}


async addData(ctx, id, oldData, category, newData) {
    const new_data = JSON.parse(newData);
    const doc = JSON.parse(oldData);

    if (!Array.isArray(doc[category])) {
        throw new Error(`Given category is not of Array type!`);
    }
    doc[category].push(new_data);
    await ctx.stub.putState(id, Buffer.from(JSON.stringify(doc)));
}
```

Fig. 4. Context-aware smart contract supporting JSON-formatted information

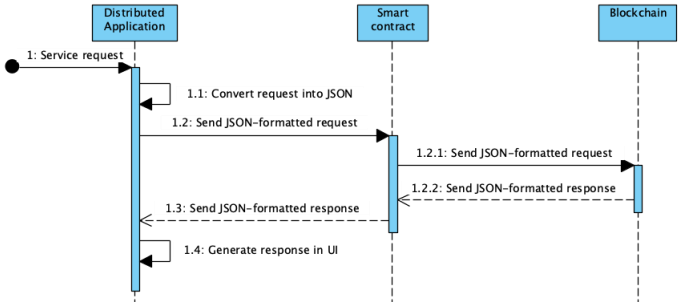

Fig. 5. Sequence diagram for a smart city service request

VI. Conclusion

In this paper we propose an architecture for applying Blockchain technology in smart cities. Thanks to its character- istics, Blockchain guarantees anonymity, optional encryption of data and traceability of goods, clean energy production and vehicles. We show how different stakeholders can benefit from using this architecture, then we make some considerations on sample workflows (i.e., the process for a citizen who requests a service or document to government institutions) and processes improvement. The context-aware approach grants scalability and lets applications interface in the same way to every service proposed in the city. Future developments regard the development of a complete simulator using smart contracts to implement some smart city services, to show how each actor can interact, exchange data and access public records.

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