



BLOCKCHAIN FOR 5G

combination of two revolutionary innovations
the blockchain system and 5G (the fifth-generation)
goes beyond networks

The 5G wireless technology is on the way to be organized around the world. The fifth-generation technologies aim to promote diverse vertical applications by getting diverse smart devices and machines with extreme advancements in terms of the highest service quality, network capacity, and advanced production capabilities. The blockchain, a rising and developing ecosystem, is offering revolutionary solutions to successfully sort out the challenges in the 5G community. According to the drastically rising capacities of the 5G technologies and the very recent explorations in the blockchain ecosystem, blockchain-built-in services are anticipated to experience prompt development and claim significant benefits for the future society.

Introduction

The 5G network is represented as the next most important stage of the world telecommunication development, alongside current successful advancements in several fields across almost all the corners of the planet. The fifth-generation system is distinguished by its most important types to support and promote EMB (Enhanced Mobile Broadband), MMTC (Massive Machine Type Communication), and LLC (Low Latency Communication) services.

The fifth-generation technology is anticipated to inspire worldwide industries and offer immediateness on customers and businesses. One of the main futuristic visions of the 5G aims to provide an individualized and sophisticated customer-focused value, making it possible to connect almost all human life aspects to communication networks. However, the quick and rapid growth and expansion of the 5G services face serious challenges in terms of security and safety, such as network reliability, information permanence, and privacy, thus before extensive deployments, these challenges must be resolved.

However, unlike the regular cellular network communications, the fifth-generation technology is going to be decentralized and universal service-oriented which has a specific focus on privacy and security requirements. Especially, the complexity rate of privacy management is higher in the 5G due to a different and massive number of smart devices connected.

Curly, the previous generation techniques were experiencing a lack of needed refinement to make the 5G networks secure and reliable.

In the community of the 5G, transparency, stability, and decentralization are the most important security aspects that guarantee the highest success ratio of deployment of new products such as data collection of IoT, self-driving cars, UAVs (unmanned aerial vehicles) and etc.

Between the present technologies, the blockchain system is one of the most promising and reliable ones that meet advanced security and privacy requirements and alter the 5G network landscape.

From a technical point of view, blockchain represents a disseminated ledger system that found its first use in the public digital ledger of crypto-asset Bitcoin for monetary transactions. Currently, blockchain technology is being used and applied in different fields, such as IoT, edge computing, smart city, and etc. In advance, it demonstrates the potential of being integrated with the 5G network communications to allow mobile network service.

The Blockchain-5G Motivation for Integration

The blockchain system is known as the innovative technology underlying the BTC. Decentralization and transparency represent one of the main ideas of the blockchain. Meaning the following blockchain does not save or store the database at any central point.

The structure and the applicability of the blockchain enable powerful and secure operational transmissions with the full advantages of corruption and vulnerability resistance. Specifically, the blockchain is easily accessible for everybody eliminating the third parties, and is not controlled by any network or governmental entities.

Definition of “The Blockchain-5G Motivation for Integration”

The blockchain ecosystem brings us the way and skill to store and organize 5G data via its highly secured DL. Especially important, by providing a spread of security measures pledge to handle security issues 5G network faces. Hence, one in all the key points demonstrated here only serves the aim of supporting network security and organization for 5G applications.

On the other hand, 5G relates to the state-of-the-art wireless community which is predicted to supply highly improved capacity, bandwidth, connectivity, and advanced provision of stable service.

Security challenges that 5G networks face

The security and privacy of these 5G networks still are the topic of unsolved challenges because of their centralized structure.

In the 5G, IoT integration cases as an example in smart healthcare and smart cities digital environments are one of the main aspects where complex security and privacy issues must be solved.

In addition, it is becoming more and more challenging to promptly identify or detect the spiteful activities from tens of thousands of transfers on large databases.

Obviously, we face another critical challenge in providing effective and advanced mobile services in terms of drastically increasing flow rate. Hence, an innovative way must be found to solve and overcome the aforementioned limitations and challenges for 5G communication networks.

Opportunities claimed by blockchain for 5G and services

Blockchain network with its groundbreaking security features introduces a new group of advanced solutions for 5G services in order to improve privacy, security, and transparency for improved and better 5G performances. Thus, 5G should accommodate and use the full potential and advantages of the blockchain system in providing digital network services and widespread coverage.

Concisely, we mainly concentrate on the most important advantages that blockchain can gain for 5G services, with keeping an eye on three main aspects, including security advancements, improvements of system performance, and simplifying the network.

- ***Security advancements:***

Blockchain intends to advance the security and privacy level of 5G networks and services by contributing many technical features such as transparency, traceability, and decentralization.

- ***Improvements of system performance:***

Blockchain usability also significantly enhances the performances of 5G systems.

- ***Simplifying the Network:***

It is considered that blockchain is able to make huge 5G service deployments with the help of its decentralized infrastructure.

Core Blockchain Elements

The blockchain ecosystem has a couple of key characteristics that are outlined as follows:

- **Data block**

- **Distributed ledger (Blockchain Database)**: It represents the type of datastore which is connected and repeated between the institutions of the P2P system. Here, each and every record contains a unique encrypted signature related to timestamp and makes the ledger reviewable and enduring.

- **Algorithms for Consensus**

- **Smart contracts**: a programmable application that is built in the blockchain system. One of the main characteristics that make smart contracts so “smart” is owing to their self-executing system meaning the following: the contracts will be executed automatically as long as the conditions have been congregated. For instance, if a person signs up for a contract for transferring the holdings, it will be transferred automatically through the blockchain network. After successful transactions, transfer data will be recorded and stored in the blockchain network as an unchangeable ledger.

Main characteristics of blockchain

- *Permanency*: This can be represented as an ability of a blockchain ledger to store transfer data immutable over a period.
- *Decentralization*: The decentralized blockchain system that does not rely upon any control center server to organize transactions.
- *Transparency*: Blockchain transparency arises from the fact that all data about the transaction on the blockchain system can be viewable for all system participants.
- *Privacy and security*: The key factors of the blockchain network are represented in its level of privacy and security, and in the use of private/public keys that it can provide. In addition, the network uses cryptographic maps to ensure and accomplish transactions between the network members.

According to analyzing the key aspects and characteristics of the blockchain, it seems to be a promising applicant for 5G communications and services by the technical provisions and benefits it can provide.

5G networks

The future mobile network generation, the 5G, has revolutionized society by giving the most sophisticated and advanced network services and performance improvements. In the following subsection, we are going to represent a full 5G network overview. In addition, the principles of 5G design are underlined in order to provide understandings into connecting the blockchain network in the future communicational services.

5G network study: within the past few decades, the world has been experiencing a major development of social and communication networks, starting from the First generation, towards the latest one. The 5G services are expected to surpass and outperform the previous wireless communication technologies and provide different service capabilities as well as stimulate the whole networking ecosystem around the globe.

Here are the key advantages the 5G network is able to provide:

- Provide the highest speed connections in the network (estimated 20GBps in certain cases);
- Provide the lowest latency services (less than 1ms);
- Reach the high mobility in the network (over 600km/h);
- Supports high-density networking and enables huge machine-type services;
- Provide availability and perception ratio in network energy consumption;
- Increases the number of engaged smart devices and enables ten-year battery life for machine-type gadgets;
- Increases bandwidth PU by 1000x

Principles of 5G design: The prompt enhancements of 5G services give us an impulse for new basic principles for the 5G community. The 5G design principle was defined as it can utilize software to attain service features in regards to flexibility, expandability, and configurability.

BLOCKCHAIN FOR ENABLING 5G TECHNOLOGIES

Blockchain use cases for cloud computing

The Cloud computing sector has attracted substantial attention in the last few years by virtue of its boundless storage resources and computing power, which can lead us towards the robust and efficient way of services with minimum management efforts.

In the century of 5G, the huge informational traffic arising from IoT machines to the cloud servers has made a series of new privacy difficulties and challenges, most importantly, containing the data accessibility, privacy, and data integrity

- Data availability
- Privacy management
- Data integrity
- Lack of Stability
- Lack of transparency

Blockchain for network slicing

The 5G networks and services give us a completely new view of unifying mobile networking and IoT management. With the purpose of supporting a different type of IoT applications, 5G depends on the Network Slicing idea, which is the multiple networks partition on the same hardware device. Thus, it gives mobile operators to section their networks for different applications, like, smart device, home, factory, etc.

Blockchain use in D2D communication

It's been anticipated that the D2D (Device-to-device) communication networks would represent an affiliated technology for the aforementioned 5G services.

For instance, blockchain intends to build a secure content sharing and transmitting project between mobile devices for D2D networks. In order to reduce computing charge on devices, edge servers will play the main role in computing power to launch mining puzzles for the blockchain. Specifically, the blockchain reveals its prompt performance in providing stimulus solutions, which aims to caching-activated customers to keep and share the content to other devices through D2D for better sharing among the devices.

Blockchain use in 5G Services

Spectrum Management

Even though 5G has experienced technological enhancements, physical (spectrum) restrictions are still major limiting aspects, which affect mobile operators and prevent them from grading their services appropriately. In addition, due to spectrum shortage in wireless communications prevents quick throughput improvements and service infrastructure.

In relation to such a traditional structure of spectrum management, the blockchain system can be a way better approach to solve the performance and privacy challenges in the 5G for spectrum management. As the blockchain represents a variety of completely decentralized databases, it also can be applied for developing spectrum management/sharing with advanced security and better performances.

Blockchain for 5G IoT Applications

In the present days, IoT (Internet of Things) has established a primary part of the future internet and gained greater emphasis from industrial entities, by virtue of which they deliver exhilarating services across different applications.

One of the main facilitators of IoT enhancements is the evolution of the 5G services. In particular, over the decade, the blockchain system has been studied and integrated with IoT 5G networks to explore new opportunities for empowering services of IoT applications. In the thoroughgoing works, we find that the blockchain mostly encourages some key applications of IoT such as Smart Healthcare, Smart City, and Smart Transportation which will be underlined as follows.

Smart healthcare

Healthcare is a business sector where organizations and other medical entities provide services, equipment, and insurance in healthcare to support the quality delivery of healthcare to patients. In addition, rising 5G networks have the capacity to facilitate applications in smart care, which will carry out the new healthcare standards like better density and super-high reliability.

The conjunction of the 5G and blockchain has the potential to enhance present healthcare systems and gain more operational benefits in terms of privacy, security, service productivity for reduced operational costs.

In such a 5G healthcare scheme, the blockchain is utilized to develop a P2P informational server that will be responsible for authenticating and recording all transactions and keep them permanent and unchangeable in a distributed ledger. Also, all transaction records are visible for healthcare community members, as well as patients, doctors, and nurses for improving the data sharing speed during treatment processes.

In particular, blockchain aims to develop and support the management of spectrum network by providing the following benefits:

- ***Decentralization:***

All the need for external authorities, informational managers, data managers, and tech managers, are eliminated by the Blockchain adoption technology;

- ***Transparency:***

As all the executed transactions are saved and stored on the blockchain distributed ledger, the blockchain built-in solution will provide improved perceptibility in spectrum use cases;

- ***Availability:***

The system participants (like mobile users) will be able to access spectrum resources provided by network providers to carry out payment and sharing operation of spectrum management;

- ***Security:***

The blockchain system nature gives an opportunity for efficient communication among service providers and users with robust security abilities against insider attacks or any kind of threats;

Smart city

The 5G network development has claimed huge business opportunities and digital metamorphosis proposes for new models of smart cities, paving the way to a wide range of services for citizens. In such a situation, blockchain can prove itself to be a promising applicant to overcome security and privacy issues as well as empower smart city services.

To make smart city management simple, the city will be divided into relatively small blocks (Smart Blocks). Each smart block will be equipped with a variety of IoT devices (cameras, sensors, etc.) controlled by the Block Admin.

In 5G smart cities, a prohibitively big amount of observation information will be constantly generated from widespread video sensors.

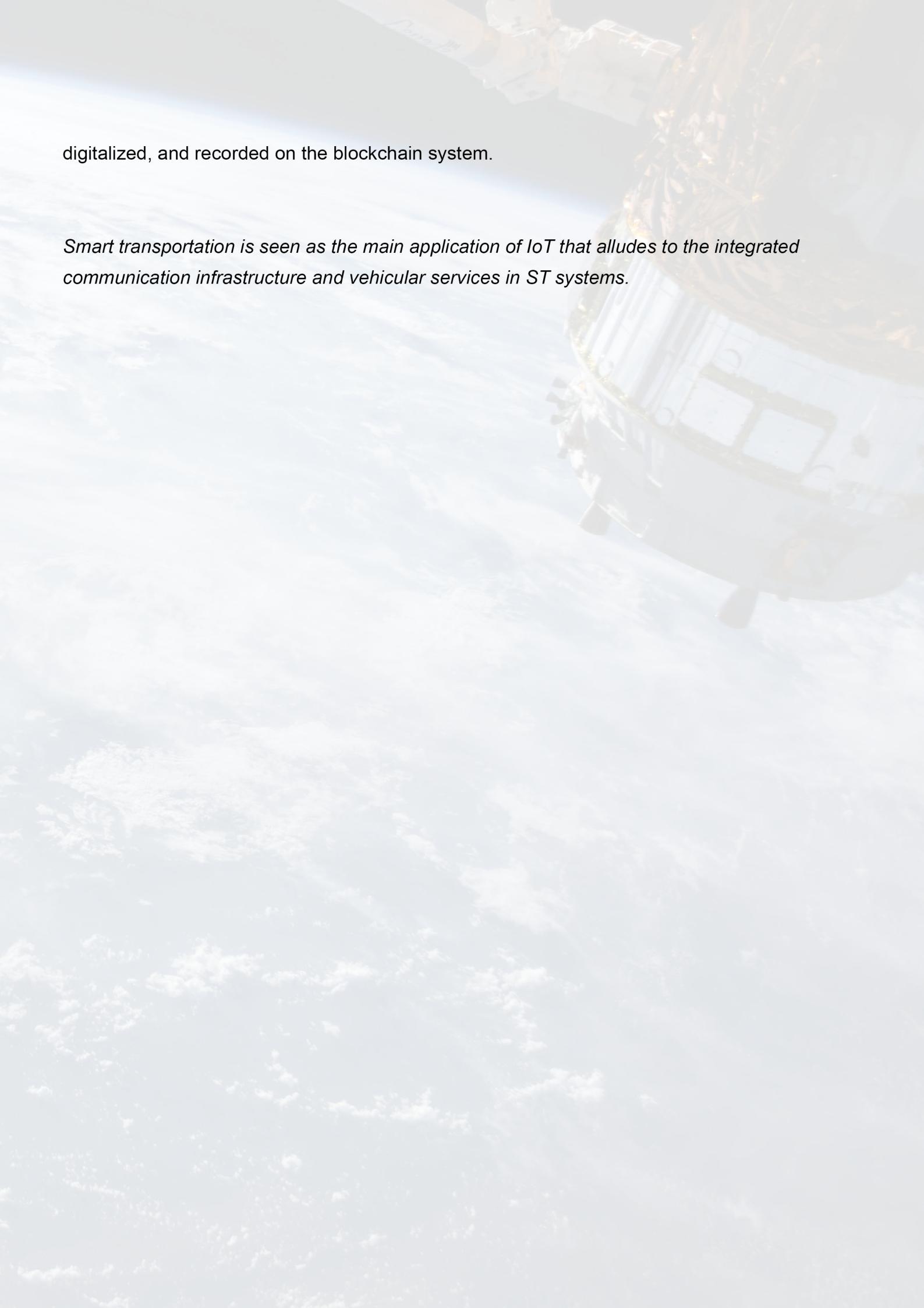
However, we face another challenge to promptly identify and detect objects of interest from thousands of record frames on the mass scale. Thus, in similar circumstances, developing a distributed ledger computing power will have the highest efficiency. From the privacy and security point of view, blockchain would be a promising solution to engaging nodes, IoT machines, and citizens, where data gathering and the business transaction will be performed on the blockchain distributed ledger.

Smart transportation

Alongside the rapid development of the 5G networks and computing technologies, the last decades have experienced an enormous expansion in ITS (intelligent transportation systems), which created a substantial effect on different aspects of our lives with transport capabilities as well as upgraded vehicles and transport services.

To facilitate the huge electric vehicle (EV) chagrin demand volume while transporting, the blockchain introduces the concept that enables P2P decentralized transactions and storage to register all EV transaction information.

Increased power loads coming from smart city citizens are all engaged to the blockchain public platform, where the supply of electricity and demand coming from users are transmitted,

A faint, semi-transparent background image shows an aerial view of a city street. A yellow double-decker bus is driving away from the viewer towards the horizon. A white car is positioned behind the bus, also moving away. The background features a grid of buildings and roads under a clear sky.

digitalized, and recorded on the blockchain system.

Smart transportation is seen as the main application of IoT that alludes to the integrated communication infrastructure and vehicular services in ST systems.

Key Findings, Challenges, and Future Research Guidelines

The combination of the 5G networks and blockchain technologies has become a sore subject now and lots of research effort have been put into advancing the blockchain system for 5G mobile services.

In the previous part of the Whitepaper, we represented a cutting-edge survey of the modern blockchain adoption attainment in 5G networks. In particular, we showed an extensive study where we covered and underlined the benefits and advantages of blockchain empowering basic 5G network services like data sharing, spectrum management, network digitalization, security, and privacy services. We do also analyze the engagement of 5G IoT applications and blockchain varying from smart cities, smart healthcare, and smart transportation.

On the basis of today's study, in this part, we will sum up the main findings of the blockchain integration in 5G networks and services. Also, we distinguish possible upcoming research challenges and open issues with the future study directions that can be viewed to promote more revolutionary solutions in this promising field.

Key findings

The thorough research of the blockchain-5G combination and applications of IoT discloses a number of key results, which possibly enables to unlock lots of opportunities and benefits for recently appearing 5G cases. This brief sub-section will underline the main findings of these advantageous technologies.

- **Blockchain for 5G technologies:** The combination of these two innovative technologies aims and intends to offer many advanced technical support and features such as decentralization, security, privacy, permanency, and transparency to entitle and develop a DNA (decentralized network architecture) for 5G networks;

- **Blockchain for 5G:** It is anticipated that blockchain will employ 5G services by creating new security features and simplifications for service management
- **Blockchain for 5G IoT applications:** Integration and engagement of 5G and blockchain can enhance recent IoT systems and provide increased performance in terms of privacy, security, and low execution costs;

Future research guidelines

Motivated by our thorough study and research on the conjunction of the blockchain-5G, we highlight feasible research directions which should be viewed in future works.

- Integrating machine learning with blockchain for 5G
- Blockchain for big data in 5G
- Blockchain for 6G

Beyond the 5G networks (B5G), or alleged 6G, will arise to provide and develop first-rate performance to 5G and face the progressively high requirements of future mobile networks implementations in the 2030s!

CONCLUSIONS

Blockchain is an emerging technology that has drawn significant attention recently and is recognized in concert with the key enablers for 5G networks due to its unique role in security assurance and network performance improvements. In this document, we have explored the opportunities brought by blockchain to empower the 5G systems and services through an advanced survey and extensive discussions based on the existing publications in the range. This work is dedicated to the lack of a comprehensive review on the integration of blockchain and 5G networks. In this document, we have presented a thorough survey focusing on the current state-of-the-art accomplishments in the integration of blockchain into 5G wireless networks. In particular, we have first provided a brief overview of the background knowledge of blockchain and 5G networks and highlighted the motivation of the integration. We have then explored and analyzed in detail the potential of blockchain for enabling key 5G technologies, such as cloud computing, edge computing, Network Slicing, and D2D communication. Our survey has also covered a comprehensive investigation on the applications of blockchain in 5G IoT networks and reviews the latest developments of the cooperated blockchain-5G IoT services in various substantial use-case domains, ranging from smart healthcare, smart city, smart transportation to smart grid and UAVs. Through the comprehensive survey on the related articles, we have summarized the main findings derived from the integrations of blockchain in 5G networks and services. Finally, we have pointed out several research challenges and outlined potential research directions toward 6G networks.