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Blockchain Adoption in Aviation: Opportunities and Challenges

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Abstract— **In the world of aviation, current evidence suggests that data management systems are majorly centralized and at the same time suffer some noted shortfalls. Whereas, under this system of operation, it is hard to guarantee trust, especially data provenance, in addition to other shortfalls. More so, there are issues of lack of sufficient governance of data immutability, transparency, auditability, and traceability; which present debilitating drawbacks to the current regime of centralized data management systems in aviation industries. Blockchain as a new normal disruptive technology promises potency and reliability in data trust, traceability, transparency, auditability, and immutability. Blockchain further emphasizes immutability for stored and exchanged data, in transaction environments, in a decentralized and secure manner. That is, in a manner whereby a trusted third-party involvement is not required. For this reason, this paper discusses and highlights the key characteristics that differentiate and denominate Blockchain. It dwells more upon Blockchain application in aviation, in its several sectors such as passenger verification, In-flight Entertainment (IFE) Monetization, Smart Contract, Digital Identity, Distribution, Payment, and so on. Also, the paper did not conclude without pointing out areas of inconclusive research in Blockchain technology to stimulate further research studies leading to new understanding, knowledge, ideation, and idea incubation.**

Keywords- Blockchain; Aviation; Transparency; Auditability; Data management

I. INTRODUCTION

The Blockchain technology is fascinating, innovative and impactful; and conceptually it is a type of distributed database, unlike the traditional database where data resides on a central system with backups and redundancy issues [1]. The present organization of the aviation sector is outdated and fragmented because most of the systems existed in isolation with little or no interconnection with other air traffic control systems, making it difficult to transmit data quickly and seamlessly throughout the interconnected and complex network of industry actors [2]. These issues can be addressed with blockchain technology. Blockchain is a database that is made up of information "blocks" that are "chained" together and are continually verified and authenticated by independent users who use the database [3,4]. Users of databases safely upload the encrypted data into blocks with time stamps. Decentralized means that the data is not actually kept in a single location, like a server, instead the data is dispersed throughout a network of nodes. The internal authentication enables the database to operate independently without the need for an external authenticator, like a bank or the government [5]. Blockchain's shared nature, which is based on a decentralized approach to data management, security, and information interchange, has the potential to significantly increase speed, transparency, and responsiveness [6,7,8]. This saves time and money while also paving the path for new business models. The adoption of Blockchain in aviation have caused considerable excitement among stakeholders in the aviation industry due to its notable benefits. The International Air Transport Association (IATA), reported that the aviation industry handles more than 50 million tonnes of freight per year, thus, amounting to about 35% of the global trade value. More so, Accenture reported that about 86% of the aviation industry are intended to incorporate Blockchain technology in their firm by the year 2023 [1, 9]. Aviation industries are complex, highly dynamic, competitive, and can be regarded as 'safety-critical industry'. Data driven decision making in the aviation industry for airlines is influence by factors such as precision level, data availability and data consistency [9-11]. However, data inconsistency in an aviation industry can affect airworthiness score, safety and finance. Blockchain can facilitate a unified view of data to reflect the actual airworthiness score, improve safety and enhances information sharing. Aircraft maintenance logbooks are manually preserved in the aviation sector as a physical ledger in the airline's possession [12-13]. A physical maintenance logbook, on the other hand, is vulnerable to being lost or faked, reducing the aircraft's airworthiness even if the

aircraft is in perfect flying condition [14]. As a result, a missing maintenance logbook reduces confidence in the aircraft's integrity and reliability and the aircraft owner must reconstruct maintenance logbooks from start, which is both time-consuming and resource-intensive. To address such concerns, Blockchain technology with a decentralized storage service can permanently preserve aircraft service records on the Blockchain ledger as well as keep immutable logs of transactions. It provides the same information to all authorized participants in order to improve transparency, reliability, availability, and Federal Aviation Administration (FAA) compliance. More so, traditional airline systems rely on direct negotiation or centralized mediation services to resolve business issues. Existing dispute resolution methods can be expensive and time consuming. Blockchain technology, on the other hand, can use smart contracts to automate company rules and resolve conflicts in a far more dependable and trustworthy manner. A smart contract is a self-executing piece of code that establishes confidence among the companies involved. Smart contracts have enormous potential in the aviation industry to efficiently keep aircraft maintenance records, check crew certificates, and monitor ground handler operations at the airport [15].

II. KEY CHARACTERISTICS OF BLOCKCHAIN TECHNOLOGY

When discussing the application of Blockchain to aviation, there are some key features it possesses that make it suitable. These key characteristics are shown in Fig. 1

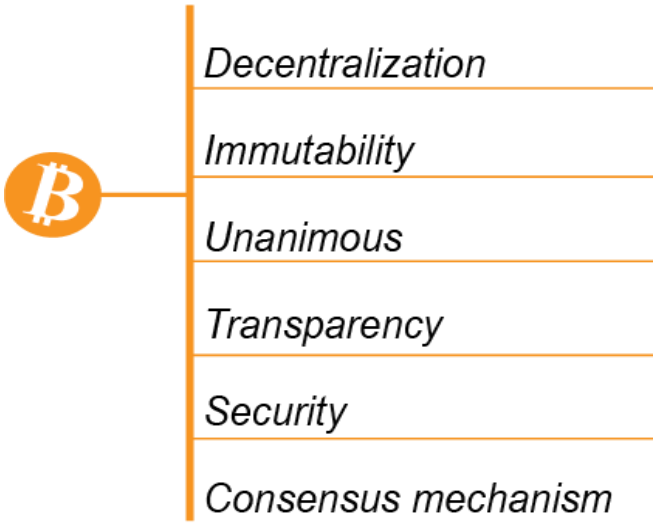

Figure 1. Key characteristics of Blockchain

A. Decentralization

The most important features of the Blockchain is decentralization, that is, no single governing body will be in charge of the nodes. Thus, performance bottleneck at the central server is eliminated. The network is instead created and maintained by a number of nodes. The ledger is same on every node in the Blockchain network. The Blockchain network's decentralization attribute offers a number of benefits [16]:

- A Blockchain network is completely ordered and fault-tolerant because it does not rely on human computations.
- The decentralized nature of the Blockchain network makes it less vulnerable to failure. Hackers must invest more money to attack the system, making failure less likely.
- There is no involvement of a third party, hence there is no systemic risk.
- The decentralized structure of Blockchain makes it easier to establish a transparent profile for each network user. Every modification may be tracked, making creation more possible.
- Users no longer have to rely on third parties to maintain and manage their assets because they are in control of their own possessions.

B. Immutablity

The immutability features of Blockchain assures that information stored in the database is temper proof. Any records that have been validated cannot be modified or reversed. As a result, no user on the network will be able to modify, alter, or delete information in the database [16-17]. Every node in the network has a copy of the digital ledger. Every node verifies a transaction's legality before adding it, and if most nodes agree that it is valid, the transaction is added to the network, otherwise, transaction is rejected. Hence, Blockchain database is considered as immutable, decentralized and secured.

C. Unanimous

Before records may be added to the network, all network participants must ratify their accuracy. A node must receive majority vote in order to add a block to the network; otherwise, the block cannot be added. A node is unable to merely add, update, or remove data from the network [18]. Every record is updated at once, and the updates spread swiftly throughout the network. Therefore, no modification can be made in the network without the majority of nodes' approval.

D. Transparency

Another significant characteristics of blockchain-based smart contracts is transaction transparency [16]. All parties in the Blockchain ecosystem can see the blockchain ledger and smart contract logic. Transparency is a distinguishing feature of blockchain that makes it valuable among centralized databases. As a result, high-transparency network nodes can be used to review, track data records, and track operations.

E. Security

The Blockchain's records are all individually encrypted. The Blockchain network's entire process is made more secure by the use of encryption. It does not follow that one can simply add, alter, or delete data on the network because there is no centralized authority. Every piece of data on the Blockchain is cryptographically hashed, giving each one a distinct identity on the network. Each block has its own distinct hash as well as the previous block's hash. The blocks are cryptographically linked to one another as a result of this characteristic. Any attempt to

alter the data would require changing every hash ID, which is just not doable. Thus, Blockchain system offers security via cryptographic encryption algorithms [19-21].

F. Consensus mechanisms

Every Blockchain has a consensus to assist the network in reaching choices quickly and impartially. Consensus mechanisms are decision-making techniques that help the networks active nodes swiftly come to agreement and ensures the system runs smoothly. Consensus mechanism uses proofs to identify legitimate blocks and prevent record tempering [22]. These proofs (proof of work, proof of capacity, proof of authority, and proof of stake) prevent fraud in the chain of nodes. Although nodes might not have much confidence in one another, they can have confidence in the network's central algorithm. Forging a non-existing record in the Blockchain system is extremely difficult, effectively eliminating the possibility of counterfeiting unless the attacker has more computing capability (at least 51%) than the network of miners. However, where many nodes join the chain, this is impractical.

III. Classification of Blockchain System

According to openness, blockchain-based systems are classified into two types: permissioned blockchain and permissionless blockchain (public blockchain). The permissioned blockchain is further subdivided into private and consortium blockchains [23].

A. Private Blockchain

A private blockchain is one in which the write permission is controlled solely by an organization or an individual, while the read permission is open to the public. The private blockchain system is the most restricted and can only be used by businesses, government agencies, or individuals. It does not completely solve the trust issue, but it does improve auditability.

B. Public Blockchain

The term "public blockchain" refers to a blockchain that can be read by anyone on the planet, that can send transactions and be effectively validated, and that anyone can participate in the consensus process. The public blockchain is the pinnacle of decentralization.

C. Consortium Blockchain

The consortium blockchain is a blockchain that only allows the consortium's members to participate. The consortium rules govern the read and write permissions on the Blockchain, as well as the participation of accounting rights [23]. Each consortium blockchain participant does not need to be concerned about the location of their data. The data they generate is only accessible to themselves or authorized individuals. It will solve data privacy and security issues while also decentralizing. It's a hybrid of public and private blockchains. Factors such as database requirements and multi-party writing should be considered when choosing the Blockchain type.

IV. Classification of Blockchain System Opportunities of Blockchain in Aviation

Blockchain has taken the world by storm reinventing the technological operations in many sectors. Aviation is one of such sectors that is using Blockchain based ideas to innovate and improve and resolve old industrial problems. Fig. 2 depict some application domain of Blockchain in aviation.

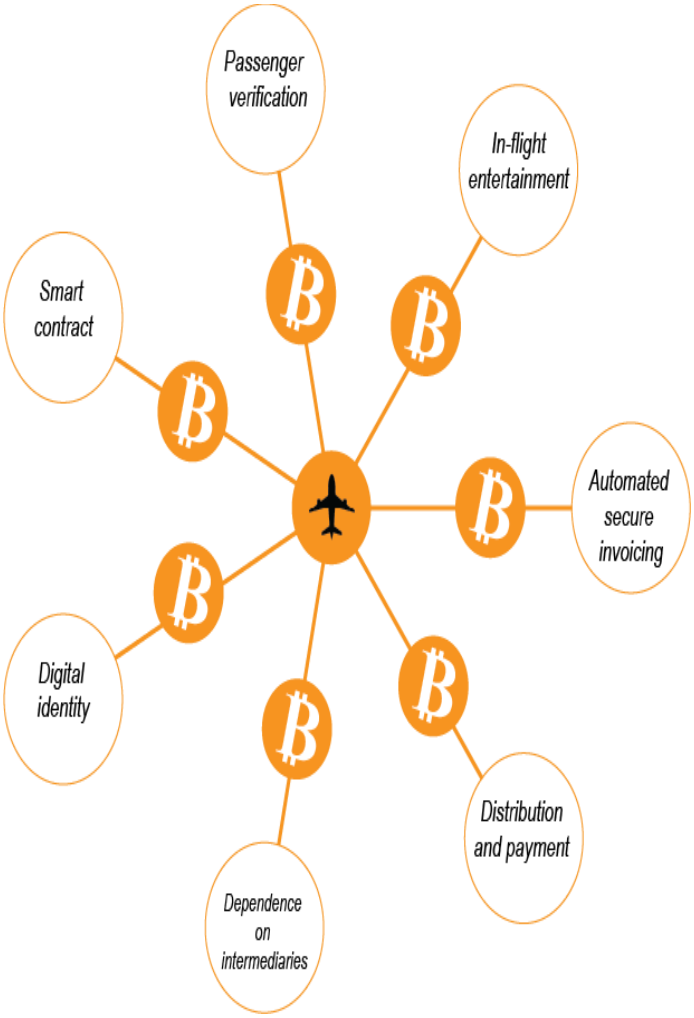

Figure 2. Application domain of Blockchain in Aviation

A. Paseenger verification

To improve human experience, blockchain can be used to optimize identity management of passengers. This would greatly reduce the occurrence of fraud and eliminate the need to physically process passports in order to verify passengers.

B. In-Flight Entertainment (IFE) Monetization

Blockchains can also be used to improve In-Flight Entertainment (IFE) systems by cryptocurrency integration to improve monetization, IFE systems can be further extended to help passengers track their luggage custody throughout the flight period.

C. Smart Contract

Many businesses (e.g., aircraft manufacturers, airlines, travel agencies, airports, ground handlers, and other industry suppliers) rely on each other for products and services to serve clients in the commercial aviation value chain. Using smart contracts, Blockchain technology may be used to simplify the purchase and payment process. For example, a smart contract may be used to handle payment upon delivery of services by encoding the amount to be paid, the services to be supplied, and the conditions agreed to by the parties involved. To minimize disagreements, automated neutral data sources can be utilized to check service delivery and circumstances. Monitoring, invoicing, reconciling, and the settlement procedure might all be eliminated as a result.

D. Digital Identity

Doing business online is becoming the standard in the commercial aviation sector and beyond. Businesses seek to expose their products and services to a broad distribution network while also understanding who they are doing business with and managing the risks associated with such engagements. Blockchain technology's inherent security qualities such as authenticity make it an excellent choice as the underpinning technology for digital identity management systems in aviation.

E. Distribution and payment

Blockchain enables airlines, travel agencies, and others in the distribution industry to interact more effectively while ensuring joint provision of travel products and services. The projected modifications may broaden the distribution reach of all parties concerned while also improving the efficiency with which travel items and services are aggregated. It also has the potential to make payments more transparent and real-time.

F. Dependence on intermediaries

Aviation companies have grown overly reliant on a small group of third parties who control most of the industry's decision-making authority and demand exorbitant fees and commissions for their services. The Global Distribution Systems (GDS) make available tickets available to travel agencies, who then sell them to consumers and corporations. The top three GDS dominate 99 percent of the indirect ticket sales industry. Most airline reservations are made through online travel agencies. Blockchain can enhance income among network participants by lowering these third-party expenditures.

G. Automated secured invoicing

In order to modernize invoice processes, blockchain security and invoicing technology like QR codes can track real-time transactions and invoice clients in real-time. To ensure proper billing based on performed contracts, the set up system gathers data from various stages during this digitalized procedure. The contracts are tracked, executed, and recorded using blockchain technology, which also detects instances of fraud. Equipment sensors verify contract compliance, and the system performs payment once the agreed-upon amount has been produced. Transaction speed, accuracy, and security can all be improved for the advantage of aviation businesses and their clients. Additionally, sensor-enabled invoicing uses fewer staff resources, freeing up workers to concentrate on more worthwhile tasks. Such an implementation would not only be applicable to business to customer (B2C) transactions, but also to business to business (B2B) interactions within the aviation industry.

V. CHALLENGES OF BLOCKCHAIN IN AVIATION

Despite the highlighted advantages of blockchain and its applicability to aviation, there are aspects of its operation could pose potential challenges when deployed. Some of these issues are highlighted subsequently.

A. Scalability

Purely decentralized Blockchains sometimes have a structure that prevents them from reaching fast transaction speeds. For example, Bitcoin's transaction rate recently hovered at 2.817 transactions per second. Scalability is thus a fundamental difficulty that has yet to be addressed by the largest decentralized systems. Vitalik Buterin, Ethereum's founder, has disclosed certain tweaks (such as sharding and plasma) that are intended to improve speed. These changes might enable Ethereum to attain 100-150 transactions per second. To put it in context, visa processes about 24, 00019 transactions a second [24,25].

B. Regulation

Another issue with Blockchain applied in different sectors is that it is unregulated which raises concerns. Considering that the aviation sector is one of the most regulated, with international bodies maintaining a strict industrial wide standard, how does the decentralized nature of blockchain fit into a highly regulated aviation industry [25].

C. Internet and environmental implications

Due to the high-power requirements a lot of arguments have been made emphasizing the huge carbon foot print of blockchain and the high power demands of a maintaining such a system. Also, the dependence of the blockchain network on internet connection means that parts of the world that do not possess a dependable internet connection may not be able to fully implement and industry wide blockchain system [25].

D. Cost of transaction

In terms of transaction fees, using decentralized platforms such as Bitcoin and Ethereum can be costly.

E. High power consumption

Another major issue with distributed digital ledger technology is the amount of power used because of the decentralized network's structure. The most often used consensus mechanism is still the proof of work mechanism. It utilize high amount of energy in solving complicated puzzles. Its annual consumption is estimated to be around 65 terawatt hour [26].

F. Selfish mining

The ability to control the system rests with nodes that have at least 51% of the total computational capacity. A node with less than that, however, can still be dangerous, according to [25]. The process of creating bitcoins requires miners to solve

challenging mathematical riddles, and the protocol is set up to compensate miners based on their productivity. In a selfish mining strategy, groups of miners joined forces to boost their profits by separating newly generated (mined) blocks from the main blockchain, resulting in a split, and only making them accessible to systems within their private network or to the general public when certain conditions are met. When the private branch is longer than the current public chain, miners will have to accept it. "Once a selfish mining pool hits a threshold (of a public blockchain), sensible miners would be drawn to join the selfish miners to gain money as compared to other pool.

VI. CONCLUSION

In this paper, we have examined how the use of blockchain technology might significantly reshape and transform the aviation business. We highlighted and discussed the key characteristics of blockchain technology as well as the prospects it can present for the aviation sector. We identified a number of recently reported case studies where blockchain technology was used to provide aviation-specific services. Some challenges that hinder the successful adoption of blockchain technology in aviation industry are presented. Our major findings as well as recommendations are summarized below:

- The aviation industry is one of the fastest-growing industry that significantly contributes to the world economy. Digitizing aviation services using blockchain technology can increase the trust of the aviation industry partners to further increase return on investment.
- The huge amount of data generated by the aviation entities require fast transaction processing and settlement.
- The performance of blockchain-based solutions is highly affected by several factors such as scalability of platforms, internet and environmental implications, regulations and conflicting interests of participating organizations in the aviation industry.
- In future, we intend to implement a blockchain-based solution for A-CDM and TAM services.

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