PERSPECTIVE

Integrating Blockchain with ERP for a Transparent Supply Chain

Abstract

Supply chain is complex today. Multi-echelon, highly disjointed, and geographically spread are some of the cornerstones of today's supply chain. All these together with different governmental policies and human behavior make it almost impossible to probe incidents and trace events in case of supply chain disruptions. In effect, an end-to-end supply chain, from the most basic raw material to the final product in a customer's possession, is opaque. The inherent cost involved in managing supply chain intermediaries, their reliability, traceability, and transparency further complicate the supply chain. The solution to such complicated problems lies in improving supply chain transparency. This is now possible with the concept of blockchain. The usage of blockchain in a financial transaction is well known. This paper reviews blockchain technology, which is changing the face of supply chain and bringing in transparency and authenticity. This paper first discusses the history and evolution of blockchain from the bitcoin network, and goes on to explore the protocols. The author takes a deep dive into the design of blockchain, exploring its five pillars and three-layered architecture, which enables most of the blockchains today. With the architecture, the author focuses on the applications, use cases, road map, and challenges for blockchain in the supply chain domain as well as the synergy of blockchain with enterprise applications. It analyzes the integration of the enterprise resource planning (ERP) system of the supply chain domain with blockchain. It also explores the three distinct growth areas: ERP-blockchain supply chain use cases, the middleware for connecting the blockchain with ERP, and blockchain as a service (BaaS). The paper ends with a brief conclusion and a discussion.

Infosys
be more

Modern supply chain: Introduction

Supply chains toward the end of the last millennium were mainly powered by internal databases with on-premise computing capabilities driven mainly by Oracle, IBM, and Microsoft databases and technologies. With the advent of the new millennium, a new generation of distributed platforms was introduced to run on cloud, enabling the outsourcing of some processes and efficient storage facilities and cost. This has helped supply chain processes to be more global with the ability to source and manufacture with the best economy, have optimized quality, be nearest to the market, and pass on more value to the customer. However, it has ended up being more complex. With these processes enabled by the system, the transactions have inefficiencies, fraud, pilferages with more and more regulations and compliance, a greater trust deficit, and need more monitoring. This has given rise to numerous codes like the Universal Product Code (UPC), United Nations Standard Products and Services Code (UNSPSC), compliance with Country Of Origin (COO) and Restriction of Hazardous Substances (RoHS), and the advent of escrow, and clearing house services to name a few.

These help supply chain be more reliable but add to its cost. The need of the hour is to bring in visibility, but it is next to impossible with the existing architecture. Even if it can be brought, having visibility can be extremely costly due to the need of resources as well as an agreement for transparency.

The global supply chain today is part of our daily life. But have we ever thought of these details when we buy products like the following?

- **Clothing / garments:** In their manufacturing / weaving, was child labor, slavery, or exploitation involved?
- **Diamonds:** Where was it mined, and does this diamond in any way influence / help terrorism?
- **Farm produce:** Where and how was it grown? What were the fertilizers or chemicals used?
- **Meat products:** How and where were the animals raised? How hygienic and healthy were they?
- **Automotive:** What are its components, and are all of them traceable till the raw materials?
- **Electronics:** How good are the components for the environment, and what will happen after I dispose of them?
- **Software products:** Can the IP be traced back and its authenticity checked till its source?
- **Furniture:** From where is the timber sourced? Are we damaging the ecology by using this product?
- **Paper:** Can I trace its origin to the forests and trees?
- **Plastic:** What happens to it once we dispose of it?
- **Cosmetics:** Was animal testing done?

Lack of transparency in the supply chain prevents the entities from verifying and validating the true value and reality of products. It obstructs tracking the environmental damage that goes into building the product. There is no way to investigate and account for illegitimate activities associated with the supply chain of the product. Such examples provoke us to question whether the current supply chain information architecture will support or provide this information; and do we need something different from what we have today?

History and introduction to blockchain

This brings us to the topic for this study — blockchain. The example quoted above points to a very pertinent aspect: can we map, link, trace, and make the entire supply chain of the product visible from cradle to grave? As of today, we can't, but there are new developments in technology and communication architecture which can make these possible. The answer to this lies in the technology of the blockchain.
The bitcoin network uses blockchain technology. A simple explanation of the term 'blockchain' is a distributed ledger, which is a list of transactions that is shared among a number of computers, rather than being stored on a central server. This distributed ledger guarantees security as well as transparency. An example of a blockchain transaction will be the register of transfer of goods between two parties (identified as two addresses in the blockchain). The transaction lodged into the blockchain will have supply-chain-relevant information like location, date, price, and quantity, which will be available in the distributed ledger. The publicly available information in ledgers would make it possible to trace back every transaction to the grassroots raw material also. The decentralized ledger would make it impossible to manipulate as a single party does not hold ownership. The cryptography-based immutable nature of the transactions would make it almost impossible to compromise the ledger. In fact, it is considered that the blockchain is unhackable. It is groundbreaking in many ways, including being the:

- World's first distributed consensus system
- World's largest distributed peer-to-peer (P2P) network
- World's first and largest write-only public ledger

It is also considered the only ledger that will become more secure with time and volume.

Protocols of blockchain

Blockchain operates in the bitcoin network, which is a decentralized network. Hence, every time a transaction occurs between the members of this network, it needs to be verified and validated so as to ensure that every transaction occurring within the network is between two individual accounts and that there is no risk of double spending. The verification is carried out by members of the blockchain network known as miners. The miners use software, their own coding skills, and computers to verify the transactions. The miners are compensated for their effort, resources, and skill. The occurrence of transactions is termed as a block. The verification of the transaction (block), the availability of the verified transaction thereafter, and its irreversibility lays the platform for the blockchain. In a specified time (in minutes), a 'block' is created comprising the transactions in the bitcoin network, which upon verification by the fastest miner becomes a legitimate and immutable block. A block can have a number of transactions over the elapsed time. The miners are compensated in bitcoins. This is where it starts to differentiate from the normal fractional banking system. The total amount of bitcoins that can ever exist is fixed at 21 million, limited by the computing power. As the quantity of money is fixed, the payment made to the miner is much like mining currency out of a reservoir.
The transactions are consolidated in a block for an elapsed time, and each block is linked to the previous transaction block through addresses. Grouping these blocks leads to the creation of blockchains. When the grouping of blocks occurs as per the protocol dictated by the algorithm supporting the creation of bitcoins, this protocol is known as the blockchain protocol. Figure 1 (below) represents the blockchain protocol.

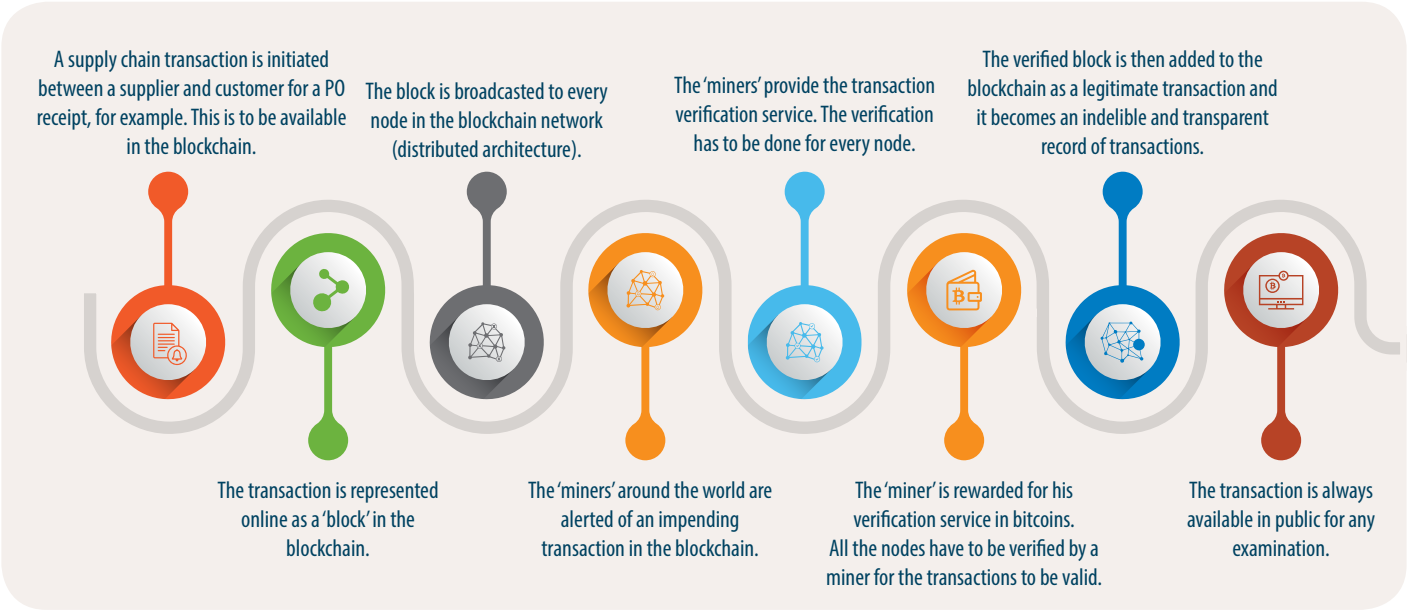

Figure 1: Protocols of blockchain

Key blockchain statistics

- Websites using blockchains: There are an estimated 498 websites that have blockchain, but essentially there are only 149 active websites currently using blockchain transactions.
- Approximately US$1.1 billion have been invested in blockchain technology.
- Payment banks using blockchain: A number of electronic payment service providers use blockchain. They are led by PayPal, followed by Google Checkout.
- 42 systematically important financial institutions are doing active research on blockchain.
- Geography-wise market share: The USA leads blockchain usage with almost 64 percent of market share. It is followed by Britain and China.
- Potential savings of a bank's infrastructure cost through blockchain is expected to be around 30 percent.
- Using blockchain technology, the potential annual savings for banks is expected to be around US$8 billion to US$12 billion.
- The blockchain market is expected to be worth around US$20 billion by 2024.
- Around 90 percent of the banks in North America and Europe are exploring blockchain and its underlying technology, while globally it stands at around 69 percent.
- Insurance fraud accounts for US$60 billion in losses each year in the US and Europe; approximately US$133 million is paid out to cover jewelry theft alone. Blockchain solutions can provide insurance companies and claimants with a permanent registry and secure verification.

Architecture of blockchain

The architecture can differ between blockchains with their underlying technology. Today, there are multiple blockchains, but primarily all of them revolve around five key attributes which define and enable them. These five attributes, in a way, power the technology which drives blockchain. These attributes ensure the solution is scalable, compliant, flexible to incorporate newer requirements, and have privacy and security.

- **Permissioned and private:** This attribute writes records exclusively for members, and any third party can be granted access and/or excluded from general access. The permissions can be architected to allow third-party access to specific data as required for the application.
- **Transparency through decentralization:** As the information in the block once verified is copied to every node, there is absolute transparency with access based on permission.
- **Immutability, irreversibility, and data integrity:** Records in the nodes are cryptographically secured, with no possibility for anyone (without key access) to change the data, so there is no threat to data integrity.
- **Scalability:** As it uses shared computer capability and servers, it has the ability to secure billions of transactions. As the information is copied to nodes, there is no need for synchronized networks, data security, accessibility, or integrity.
- **Security:** Blockchain networks support data encryption, decryption, and enforces complex permission for participants and third parties.

These five attributes can also be considered as the five pillars of blockchain, which can fit into different layers of blockchain computing. Each of the pillars enables a certain type of layer. The total blockchain operations are segregated into three layers with each layer having a specific purpose and a role. These five pillars support the three solution layers: blockchain layer, data store layer, and the application layer. Figure 2 represents the architecture visually. The figure explains how the solution layers are connected to others through the pillars.

Blockchain layer: The blockchain layer maintains the 'pointers' or 'hashes' of transactions. These represent the notifications to a status change and validate the integrity of the data. The blockchain layer connects to the next layer, which is the data store layer. The blockchain layer refers to the pillars of transparency through decentralization, immutability, and data integrity.

The data store or data collect layer: The blockchain layer refers to the hashes (addresses) while the data is stored in the data store or the collection layer. The data which is stored or recorded in a private data store or collection layer can also behave like a distributed relational database which can be connected to the other layers. The data store or data collect layer is arranged through auto-hash transaction sets onto the public chain at required intervals. A third party cannot derive any meaningful information from the data store unless they have specific keys, which allow them to decrypt each individual data record. This layer refers to the pillars of permission, scalability, and security.

Application layer: This layer processes and interacts with the two above-mentioned layers and converts into a useful business application. The application layer is the 'connector' into and out of the data store / data collect layer with the blockchain layer. The application layer will have monitoring units that identify changes in the blockchain layer, read the pointers, get the decrypted data from the data store layer, and do the final validation. This layer can also interact with other ERP applications like Oracle, SAP, etc.

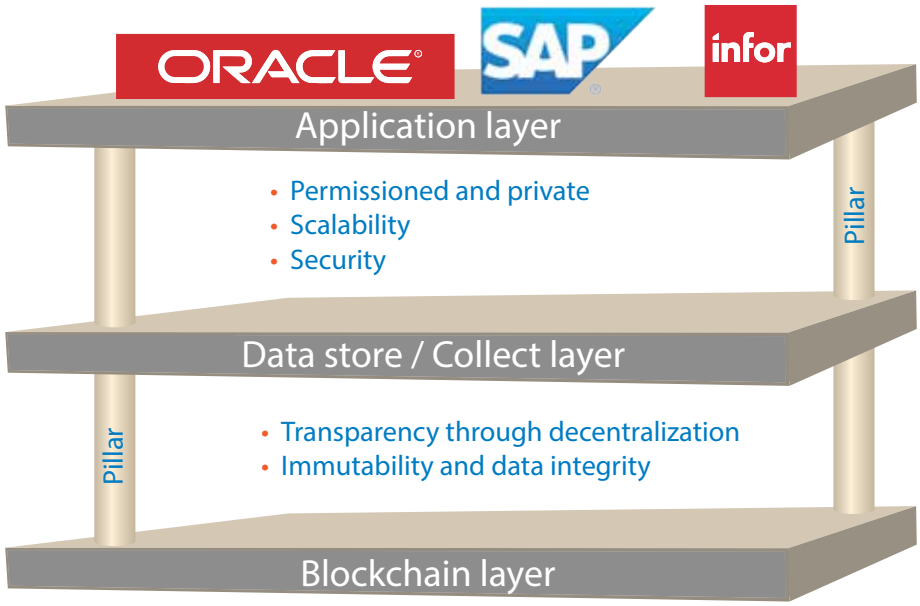

Figure 2: The general architecture of blockchain

The roadmap and challenges for blockchain

As we go further into our understanding of blockchain and dive deep into it from various aspects, we find a very obvious trend. Blockchain technology has immense potential to benefit enterprise applications, but as with any innovation, it leads to specialization. The reason is, there is an immense opportunity for multiple vendors to jump into the fray, offering variants and specific business use cases, heating up the competition and differentiating out from others. In order to differentiate, everyone comes up with a specialization. This leads to multiple blockchains existing in parallel. There can be a parallel drawn between the early to late 80s ERP products and blockchain. In the mid to late 80s, there were certain ERP products which came into the market like those of SAP, Oracle, BaaN, Mapics, JD Edwards, and PeopleSoft. There were certain specialties in each of them, like, SAP was for logistics, Oracle was for financials, PeopleSoft was for human resources, and JD Edwards was for manufacturing. It is assumed at that point of time, there were approximately 20 other ERP vendors that were getting built. But slowly, some products improvised, enriched, improved, and ultimately survived as we know them today. Similarly, in blockchain, there are multitudes of them existing today with very specific applications. Blockchains will need to acquire functions and capabilities that can enable enterprises to streamline or improve their business processes. These could be in developing platforms, monitoring tools, standards, regulatory considerations, etc. With the development of these functions, the blockchains have to be interoperable with enterprises and with each other through specific standards. With these, they can flourish and be easily adopted in enterprises. Today, blockchains are plagued by many limitations and challenges. Some of the major limitations are as follows:

- **Interoperability:** The interoperability has to be between established enterprise platforms like databases, ERP systems, and also among blockchains.
- **Regulatory and legal acceptance:** Blockchains have no legal framework. There is no single ownership, so a legal framework on territoriality for issues like jurisdiction and the applicable law needs to be there. This is important as each network node may be in a different geography with a different legal law or enforcement.
- **Central administrator for blockchains:** Today there is no central administration or administrating body responsible for the distributed ledger. This may lead to a concern that there is no person, party, group, or organization eventually responsible for the functioning of distributed ledgers and the information contained within.
- **Validity of the information stored:** There is a need for a legal deed declaration of ownership of the existence of an asset on the node or of the information with a genuine backing of the proof of ownership or existence of the said asset.
- **Beyond financial transactions:** Today, most of the blockchains are financial transaction validation-oriented, but they have to diversify into other areas like manufacturing, procurement, logistics, and HR. Once it diversifies, the growth will be more phenomenal.
- **Openness through multiple partners:** With enhanced decentralized auditing and anti-counterfeiting, the blockchain interaction can help remove central authority and usher in an era of open yet secure interaction.
- **Standardization:** Standards are required to facilitate the interoperability between blockchains. This will also enable security and compliance for enterprises to interact and share solutions and transactions. These standards can be in XML (eXtensible Markup Language) or EDI (Electronic Data Interchange) formats, which are an accepted form of communication.
- **Blockchain as an enterprise chain infrastructure:** Blockchains today are designed as standalone systems with a specific purpose. This needs to be changed to blockchains as enterprise chain infrastructure, enabling key enterprise activities and transactions both within and across its partners.
- **Technological limitations:** Today there are multiple blockchains existing with their own area of specific application. There is a lack of common technology that can connect these as well as connect to other enterprises and transactional systems.
- **Health monitoring of blockchain:** As with any system, the health monitoring of blockchains is going to be crucial. There has to be a renewed focus on the aspects and parameters which will ascertain that things (not just the transactions) are good within the blockchain.
- **Latency:** Blockchains suffer from high latency as there is a time lag between the verified block of transactions and their addition to the ledger. For some of the leading blockchains, this lag varies between 17 seconds and a minute, which is way more than the average database transaction time – it can happen within a few seconds.

Among all the challenges discussed above, interoperability, standardization, and technological limitation are the three major challenges for the expedited rate of adoption of blockchain in mainstream business, as in the well-known case of Ethereum and Hyperledger. But apart from them, there are numerous others like Ripple, Eris, Coinprism, Factom, Emercoin, Algorythmix, La'Zooz, OpenBazaar, Hijro, and Skuchain to name a few. Transactions among them is a challenge and the need of the hour. There are independent software vendors who are developing individual connectors of some ERP or transactional systems with these blockchains. However, the need is to have a more open, standardized, and interoperable system where any ERP or transactional system can connect to the blockchain. With greater connection and more popularity, it will easily merge into the mainstream of business.

Blockchain and its synergy with enterprise applications

As we discuss blockchain and understand how it can influence our daily life, it becomes important that it is able to connect to various business application systems like enterprise resource planning (ERP), customer relationship management (CRM), warehouse management system (WMS), manufacturing execution systems (MES), etc. Only then will it enable the mainstream customer to achieve business success through blockchain. There are a lot of benefits in integrating these systems with blockchain including:

- As these systems build, track, purchase, and ship products, integrating with blockchain will provide a copy of this information into the network which is immutable and indelible and can be tracked and used for reference any time, for any purpose.
- As the ERP systems generate financial transactions, integrating with blockchain will help make these financial transactions transparent and reliable.
- Integration with ERP, WMS, and MES systems will reduce disputes over invoices, shipments, returns, and purchases.
- Integration with ERP, WMS, and MES systems will bring in transparency of the origin, movement, and possession of goods
- It may help in tracking of faulty components in case of a long bill of material and a faulty part driving the entire assembly to failure.
- With CRM, it can bring in transparency around customers and the chain of ownerships.

The benefit in integrating the ERP with blockchain is twofold. Firstly, it will bring in transparency, and secondly, it can reduce the cost of tracking and reporting which is significant, considering multi-echelon and multi-staged supply chains.

The enterprise-ready blockchain capabilities have to address the business processes so as to help them get into the blockchain network. Research and efforts have already started to connect the ERP with the blockchain network. Let's take the example of Finlync's distributed ledger division. It is considered the world's first blockchain-agnostic integrator for ERP systems. Finlync has developed a seamless plug-and-play integration for SAP, Ethereum and Hyperledger blockchains, and more to follow suit. Skye, a Norway-based company, has more versatile products to offer. It has developed integrations of SAP with other blockchains offering integration services in finance, HR, and supply chain.

There are three main potential growth areas in the supply chain domain. First is the advent of middleware technologies which can connect the ERP systems with different blockchain networks, second is the identification and development of use cases in the supply chain which can benefit from the blockchain network, and third is the blockchain as a service (BaaS).

1. There are already some companies that have developed middleware, and are further improving on it. Let's take the case of Microsoft's Project Bletchley. This is an open source framework to allow integration of blockchain networks with many applications. It focuses on security and governance requirements and, therefore, includes features such as a gateway or identity, key, and crypto services to allow non-blockchain clients to communicate with the blockchain network. Interledger is a lightweight blockchain protocol and integration framework to connect different blockchains and other interfaces, such as banks, PayPal, or Skype. Even established middleware vendors like Software AG or TIBCO Software are helping integrate and correlate blockchain events with the rest of the enterprise's architecture.
2. There are many use cases possible in the procurement and logistics area of supply chain which can leverage the blockchain network. For example, as per survey results of IBM, there are more than 100 million dollars of invoices worldwide which are in dispute between the buyer and supplier at any given point of time, and it takes an average of 44 days to resolve it. This can easily be avoided up to approximately 90 to 95 percent using blockchain. The contract, proof of origin, proof of receipt, proof of delivery, and proof of payment, can all be transmitted to the blockchain network which will be authenticated and stored. Then in case of a dispute, the blockchain network data can be accessed to check the accuracy, and things can be settled in minutes. Similarly, in the case of discrepancies between the customer and vendor on the price or discounts, this data can be transmitted to the blockchain network, which will then be authenticated and stored. In case of dispute, the blockchain network data can help settle the matter in minutes. Another use case in supply chain is that the procurement information like purchase order (PO) and purchase agreements, which are held in the ERP system, can be registered in digital formats in a blockchain. These digital assets can be available only to members with the private key, and can be referred, thus removing the need for physical movement through email, mail, or fax. It will be completely transparent and public with sensitive information being accessed only by members with private keys. Another powerful use of blockchain can be the replacement of EDI. Today, EDI messages are transferred across members using blockchain nodes with confidential data stored / accessed through the private key. Document attachments in sales orders and purchase orders such as contracts, agreements, or certificates can be removed in the transactional system and can be made available in blockchain that will be attached to the transactions, bringing in complete transparency and ownership. Global trade value in the year 2013 reached almost €13 trillion, out of which almost 2.5 percent were counterfeit

and pirated products, making it worth almost €338 billion. With blockchain and its ability to track products, it can significantly reduce such trade loss.

3. For most of the enterprises, it is challenging to invest upfront in creating a blockchain network and to also bring in other relevant parties into it. So this gives rise to the concept of blockchain-as-a-service (BaaS), where they will not build their own infrastructure for blockchain but share an existing one. There are companies which are developing these architecture, frameworks, and platforms. For example, IBM has a blockchain network on Bluemix service console which leverages the Hyperledger project under the hood. Similarly, Microsoft's blockchain as a service on Azure uses the Ethereum platform. In addition, Microsoft partners with various other blockchain vendors like Ripple, Eris, Coinprism, and Factom. This is definitely a growth market area.

Conclusion and discussion

Based on the analysis thus far, it can easily be concluded that a lot of research has already been done on blockchain with versatile applications. However, the field is still wide open. The development of blockchain from the bitcoin network is examined with a detailed study of protocols for validation and address hashing in a distributed network with the publicly available information, thus making the information unhackable, which is the linchpin of transparency and authenticity. The paper takes a look at the most general five-pillar, three-layer architecture common in many blockchains which are robust, inclusive, proven, and poised for growth. The challenges and limitations are explored and detailed in the area of blockchain. The challenges open up the areas of focused research and new ideas / products. Usage of blockchain in financial transactions has always been the focus, but this paper takes a look at the wide-ranging applications of supply chain, as is evident in various use cases. From a supply chain perspective, there is a lot of synergy between blockchain with enterprise systems and is studied in detail along with future growth areas. Through this research, it is apparent that there are three areas of evolution for the blockchain: use cases on supply chain for ERP-blockchain integration, the middleware for connecting the blockchain with ERP, and blockchain as a service (BaaS). These are areas which are developing very rapidly and are opening up big opportunities. Finally, it is about the future where companies will be eligible for trade only when they are blockchain-certified.

Trivia

The author of the first paper on bitcoin, which further introduced blockchain by the name of Satoshi Nakamoto, is anonymous as of this day. No one knows who she/he is.

Acknowledgements

The author would like to thank Muralidharan Srinivasan, Srikanth Sripathi, and Somnath Majumdar for their detailed review with constructive suggestions, which has enhanced the content and readability of the paper.

References

[1] https://bravenewcoin.com/news/the-5-pillars-and-3-layers-to-enterprise-blockchain-solution-design/

[2] http://infocastinc.com/industries/considering-blockchain-for-an-enterprise/

[3] https://bitcoinmagazine.com/articles/beyond-bitcoin-how-the-blockchain-can-power-a-new-generation-of-enterprise-software-1443635470/

[4] http://www.libra.tech/blog/is-blockchain-tech-enabling-next-gen-erp/

[5] https://www.k3syspro.com/blockchains/

[6] https://www.infoq.com/articles/blockchain-middleware

[7] http://www.the-blockchain.com/2017/03/29/hijro-partners-sap-blockchain-technology-opens-trade-finance-beta-ariba-supplier-network/

[8] https://www.youtube.com/watch?v=jHxfLdmha58

[9] https://www.youtube.com/watch?v=8xBrjf05b-w

[10] https://trends.builtwith.com/payment/Blockchain/Market-Share

[11] http://expandedramblings.com/index.php/blockchain-statistics/

[12] http://www.industryweek.com/supply-chain/blockchain-next-evolution-supply-chains

[13] https://www.slideshare.net/hughterry/blockchain-for-insurance

[14] https://euipo.europa.eu/ohimportal/en/web/observatory/mapping-the-economic-impact

About the Author

Arnab Banerjee

Principal Consultant – Process and Domain, Enterprise Application Solutions, Oracle Practice, Infosys

Arnab is a Principal Consultant with Infosys, consulting as a Program Manager or a Solution Architect. Previously he was a Supply Chain Program Manager with a communication device manufacturer. Overall he has more than 15 years of consulting and business experience in the manufacturing, supply chain, and ERP domains in the US, Europe, and Asia. To his credit he has 26 international publications in the form of international journals, conferences papers, case studies, book chapters, and white papers. He has 15 years of consulting experience with clients in Asia (Japan, China, and Malaysia), North America (USA, Canada, and Mexico), the United Kingdom, and Western Europe (France, Germany, and Sweden). His research interests include operations research and information technology applications in supply chain management, green / reverse supply chain, lean initiatives, theory of constraints, IT architecture, business operations, and transformations and HR aspects in supply chain and humanitarian logistics. Arnab holds a Ph.D. in Supply Chain Management, a master's degree in Industrial Engineering, and a bachelor's degree in Mechanical Engineering. He is a certified six sigma black belt champion.

He can be reached at Arnab_banerjee08@infosys.com

For more information, contact askus@infosys.com

Infosys be more