Trust the System – Blockchain Technologyand its Application in Education

Ms. Smita Mehendale
Symbiosis Institute of Management Studies
Constituent of Symbiosis International (Deemed University), Pune, India

Dr. Aakash Kamble
Indira Global Business School, Pune, India

ABSTRACT
The basis for cryptocurrencies like bitcoin lies in Blockchain technology. Since its inception, Blockchain technology has gained importance and is been applied to various areas like, smart cities, smart contracts, finance, sharing economy, commerce and supply chain management. Blockchain technology creates an environment of decentralization wherein any third party can neither control the transactions nor the date.Every transaction ever conducted is available for verification in a public ledger for posterity. The present paper explores the application of Blockchain technology in education sector specifically related to credit system and teaching-learning outcomes. The article first discusses the basics of Blockchain technology with the different layers within it followed by the application in education. The future possibilities of Blockchain technology in education are discussed along with the benefits and challenges.

Keywords: Blockchain technology, smart contracts, education, educational evaluation, learning outcomes.

1. INTRODUCTION

With the advent of Bitcoin in 2009, the Blockchain, the technology which forms the basis for Bitcoin was the first cryptocurrency across the globe(Desjardins, 2016). During this time, Blockchain the underlying technique (X. Li, Jiang, Chen, Luo, & Wen, 2017) has been applied to various fields ranging from healthcare(Azaria, Ekblaw, Vieira, & Lippman, 2016; Zhang, Xue, & Huang, 2016), to economics(Bylica, Glen, Janiuk, Skrzypcaz, & Zawlocki, 2015; Huckle, Bhattacharya, White, & Beloff, 2016; Hurich, 2016; Viriyasitavat & Hoonsopon, 2018; Xu et al., 2016), software engineering(Czepluch, Lollike, & Malone, 2015; Xu et al., 2016) and internet of things(Dorri, Kanhere, Jurdak, & Gauravaram, 2017; Hammi, Hammi, Bellot, & Serhrouchni, 2018; Panarello, Tapas, Merlino, Longo, & Puliafito, 2018; Sun, Yan, & Zhang, 2016). Use of Blockchain in Bitcoin was just the start, this underlying technology is adopted by other cryptocurrencies as well. The trust-free, transparent and secure nature of Blockchain technology helps in use of it in other areas as well (Beck, Czepluch, Lollike, & Malone, 2016). The potential applications and benefits of Blockchain technology also extend to humanitarian, social, political and scientific domains, enabling groups to harness its capacity to address real-world problems (Swan, 2015).

Decentralization is the most important advantage of Blockchain as it helps in establishing disintermediate, peer-to-peer transactions. Further, it enhances the coordination within the distributed ledger by decentralizing control along each individual nodes with the help of such techniques as time-stamping, economic incentive mechanism, data encryption and distributed consensus algorithms(Yuan & Wang, 2018).Blockchain technology is widely dubbed as one of the most powerful disruptive innovation and has been ranked the fifth among mobile/social networks, computing mainframe, personal computer and the Internet itself (Swan, 2015). Blockchain technology is radically reshaping the behaviour models of organizations and individuals (C. L. P. Chen & Zhang, 2014; Yuan & Wang, 2016). Trust-free systems make use of the clue to utilize Blockchain technology to automatically generaterecords of transactions executed in the past that are publically available, unchangeable, and consensual that are administered by the entire system hence mitigating issues related to trust in the systems (Greiner & Wang, 2015)(Greiner & Wang, 2015).

The Blockchain applications are currently in 1.0 and 2.0 level. People in the industry and academia are still oblivion to the potential offered by Blockchain technology. Many have still not been introduced to technology yet. Studies focusing on its application in the education sector have been carried out(Devine, 2015; Sharples & Domingue, 2016).

With the use of a distributed peer-to-peer structure, Blockchain technology ensures accountability, management of identity, transparency, ownership through consensus and privacy and trust are built in built at

the system level. As is true with other sectors, Blockchaincan bring about drastic changes in education in multiple ways too. This paper explores the Blockchain applications in education sector covering aspects of learning outcomes, along with traceability and authenticity of transcripts and tutoring. Innovative paradigms that can be introduced by these applications have been discussed.

2. REVIEW OF LITERATURE

2.1.THE CONCEPT - BLOCKCHAIN

Blockchain as a concept came into existence in 2008. It supported the establishment and exchange of theBitcoin, a type of cryptocurrencywhich does not require a central authority that controls the process (Magazzeni, McBurney, & Nash, 2017; Nakamoto, 2008). While the primary driving force for Blockchain technology has been cryptocurrencies, new avenues for wider applications of Blockchain apart from finance started surfacing. Blockchain contains decentralised storage of data that describe transactions(Di Ciccio et al., 2018).A significant impact of Blockchain is seen on cryptocurrency, financial matters and even other socio-economic happenings, it is been around for quite some time now. It is a collection of disruptive innovation combining existing technologies in cryptography, economics, and computer science (Yuan & Wang, 2018).

Against traditional bank which is centralized in nature for all the transactions, the transactions in case ofBlockchain network are stored on different peers that form a part of the network. Such decentralization leads to direct exchange amongst the participants with no need for third party observer. Transactions here are organized into blocks, many blocks are grouped together resulting in queuing of blocks thus leading to a logical series of transactions. Cryptography, peer-to-peer networks, market mechanisms and consensus between members provide trustworthy addition of new blocks to the chain (Mougayar, 2016). Even under a scenario leading to faults arising in the operation, the data integrity and transparency in a Blockchain is not hampered. Addition of a block can be done only if a majority of those in the network consent to it.According toBentov, Gabizon, & Mizrahi (2016), the common techniques used for consensus in a Blockchain application are ProofofWork (PoW) and ProofofStake (PoS). The below section discusses a six-layer model for Blockchain by standardizing and characterizing its architecture and major components. The detailed structure is shown in figure 1.All transactions are signed but signee's identity is not disclosed. Hashing function facilitates consensus and anonymity.

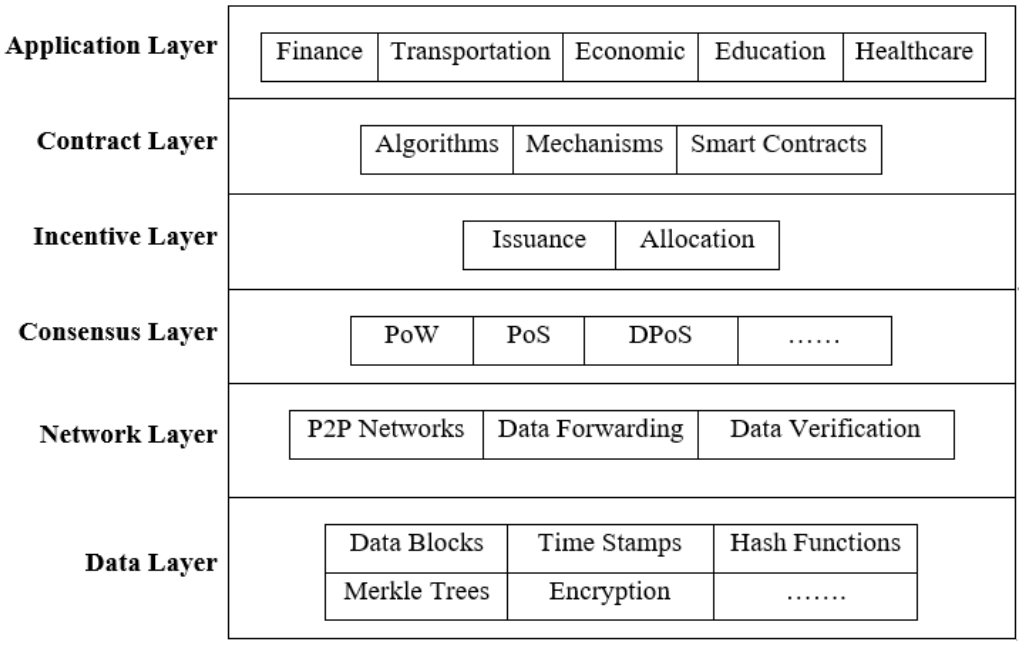

Figure 1. Model for Blockchain

The directional deterministic function maps the inputs with a fixed-size output using a cryptographic hash function. So for the given same input, the same output is returned always, however, the other way round is not possible. Data layer is responsible for providing the necessary techniques for manipulation of the collected data from various sources like physical, cyber and social(Wang, Zheng, Zhang, Zeng, & Wang, 2017). For every new block generated for a given hash function, the data and contents of the previous hash are also required.This leads to a sequential ordering of each and every block which also record the hash values of the transactions carried for that particular block(Di Ciccio et al., 2018). Any alteration to the

transaction changes the value of the hash of its block and breaks thechain formed.The key difference in the private and public Blockchain exists due to the visibility of network; wherein public network enable everyone to join and inspect, and private network allows only those invited. On the contrary, permissioned Blockchains and permissionless are differentiated based on their ability to add block on to the chain; wherein the former only those allowed can add the blocks, while in the latter all peers within the network can add the blockswhich are also called participate to consensus (Di Ciccio et al., 2018). Execution of smart contracts is allowed by Blockchains through reaction of software programsbased on triggers generated by the environment of the Blockchain or by the users of it(Governatori et al., 2018). Unlike distributed databases, distributed ledger systems consist of computational platforms.

In the network layer, distributed networking, data forwarding and verification mechanisms are present forming decentralized communication models. Peer-to-peer networks form an important basis for this decentralized system making it dynamic and open in nature. The nodes further seed into the network, thus blocks are verified on the basis of predefined checklists and discarding the invalid blocks. Under consensus layer,Blockchains employ a range of consensus algorithms that guarantee consistency of the data along with the ability to tolerate faults of the shared ledger among distributed nodes(C. L. P. Chen, Wen, Liu, & Wang, 2014; Lakshman & Agrawala, 1986). Whereas the focus of Blockchain models is primarily on dynamic environments that are open with many trustless entities with devious failures.(Fan & YI LT, 2013). The most extensively used algorithm is proof-of-work that requests nodes to repeatedly participate to conduct mathematically challenging computation for authentication of the data(Kraft, 2016). The block that is winning is then permitted to attach its block on the distributed ledger. Hence using proof-of-stake (PoS) new block get produced based on the node having the leading amount of predefined stakes like coins to produce it. Other forms of PoS algorithms, can be proof-of-movement and even the delegated PoS (DPoS). Among the POX algorithms, PoS and DPoS that are non-computational-intensive algorithms are predominantly suitable for many of the lightweight systems within Blockchain ecosystems(Yuan & Wang, 2018).

In the incentive layer, economic rewards are incorporated into the Blockchain structure. In principle, the data authentication and block formation process that is driven by competitions in consensusis regarded as crowdsourcing by the virtue of the computing power given by the participating nodes(Yuan & Wang, 2018).

The nodes act as self-regardingrepresentatives, thus making it imperative to have incentive friendly mechanism so as to guarantee revenue generation and maximization of individual and that it falls in line with the larger system objective of a pledging a safe and trustworthy network (J. Li, Ni, & Yuan, 2018; Yuan, Wang, & Zeng, 2017; Yuan, Zeng, Zhao, & Li, 2015). The contract layer of the Blockchain houses the smart contracts and the algorithms which are the business logic required to initiate the static data and other forms of it like the assets stored or even the money (Yuan & Wang, 2018).In principle, the smart contracts are the one which self-authenticate themselves based on the response instructions generated from the Blockchain network. All the possible application which can be worked based on smart contracts are present on the application layer of the technology. Even though being in its infancy,Blockchain technology has witnessed remarkable growth (Yuan & Wang, 2018).

3. BLOCKCHAIN TECHNOLOGY IN EDUCATIONAL APPLICATIONS

3.1.CURRENTAPPLICATION OF BLOCKCHAINS IN EDUCATION

Blockchain technology is been applied in some universities and institutes alike, with a purpose of supportingmanagement of academic degree and also for evaluating the outcomes of learning(Sharples & Domingue, 2016; Skiba, 2017). Contents related to education like the formulation of the transcript and related to formal learning like the contents and outcomes as also the achievements of students and academic certificates can be controlled by Blockchain(G. Chen, Xu, Lu, & Chen, 2018). The inclusion of formal educational context mentioned above and also the informal learning contexts like research experience, skills and participation also get included in the Blockchain. Blockchain provides safe and secure access to this data as and when required. Speaking of examples, University of Nicosia manages students' certificates awarded after completing MOOCs using Blockchain technology (Sharples & Domingue, 2016). Hoy, (2017) studied Sony Global Education's use of Blockchain technology for creating a worldwideevaluation platform to make availablefacilities for datastoring and degree management. There are institutes and companies teaming up for various educational purposes like the creation of digital badge and identities for online learning based on Blockchain technology (Skiba, 2017).

To put things in perspective, figure 2 shows a minimalistic Blockchain architecture for the education sector. Four parties involved in the architecture are a student, university, teacher and the Blockchain agent. The system is supposed to be trustworthy due to the Blockchain agent present who will authenticate and encrypt

the databases. Consider the example of student transcripts. The students give the examination and undergo an evaluation which is authenticated by the teacher for that course. The university issues the transcript upon successful completion of the course. The Blockchain agent or layer encrypts the data based on inputs from the teacher (the grades) and the university (authentication). The teacher provides the information about the grades in the form of a block added to the chain wherein the previous block represents the registration details of the student created by the university. Further, the block of grades is authenticated by transcripts are generated by the university forming a new block ahead of teacher's block. The student has access to the transcripts but cannot modify the data. Any modifications will lead addition of new block which will not correspond to the previous block hash function, thus resulting in non-acceptance.

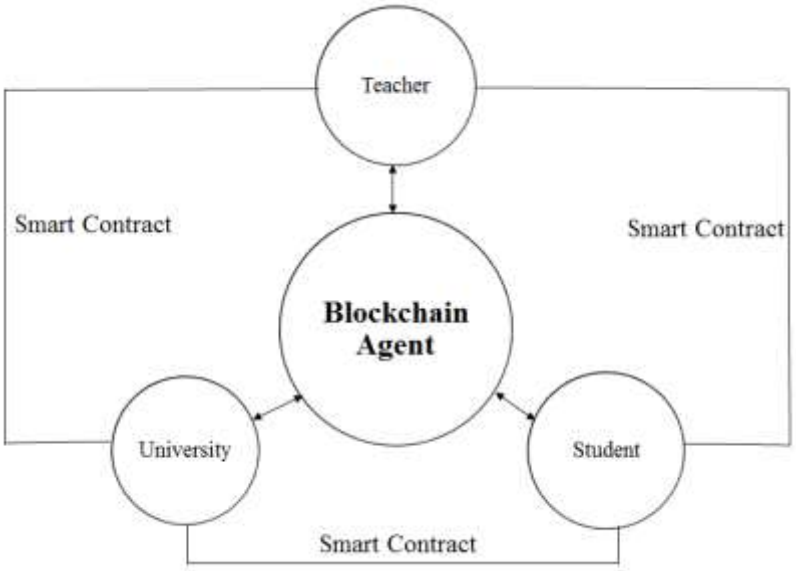

Figure 2. Education system using the architecture of Blockchain.Data is sent from the transactions of each layer to the Blockchain. Additionally, smart contracts are used to facilitate communication between the layers that manage the articles. The smart contracts are used for establishingidentifications and authenticating of data.

Issues pertaining to the education system like degree fraud can be reduced due to Blockchain technology. Degree fraud refers to counterfeiting of educational degrees by using counterfeiting technology and scrambling the bar code tags on them. Application of Blockchain technology ensures linkages between the user and their credentials created and secured using hash functions. Immutability and trustworthiness of the technology make the data tamper proof and increases the reliability thus reducing the degree fraud.

3.2.FUTURE INNOVATIONS IN EDUCATIONAL APPLICATIONS USING BLOCKCHAIN TECHNOLOGY

Beyond the purview of transcripts management and evaluation of students, this technology can be usedin education in many inventive ways. Great potential exists for both the learners and the trainers under Blockchain technology with applications ranging from formative evaluations, designing activities pertaining to learning and actual implementation and tracing overall development and related processes. Some areas of application are mentioned below.

3.3. SMART CONTRACT ADMINISTERED ON ETHEREUM BLOCKCHAIN

The Blockchainsystemcalled Ethereum is a computer protocol that triggers an actual contract termed as a smart contract (Kosba, Miller, Shi, Wen, & Papamanthou, 2016). This smart contract facilitates contract negotiation, implement contract executive, simply contract terms and verify contract fulfilment state. Smart contracts provide a precise and unique identity to the parties involved in the particular transaction (subjects of contract)using the rights and obligations of both parties in the form of code in a digital way.As compared with transactions that are of traditional nature, smart contracts not only drastically reduce the costs of the third party but also ensures the security of the transaction security and reliability.

Smart contracts are stored on a Blockchain and effectively small computer programs, which perform tasks under definedcircumstances. To simplify further a smart contract can be stated as an announcement of "transfer A to B if C occurs" (Grech & Camilleri, 2017). In contrast to regular contracts, Smart contracts are self-executing in nature wherein the parties to the contract execute it upon reaching an agreement or

consensus. In a smart contract, the transactions take place automatically when appropriate conditions are detected and met, thus making in self-executing in nature.Smart contracts can solve many issues in the education field if the students and teachers carry out learning activities based on it.

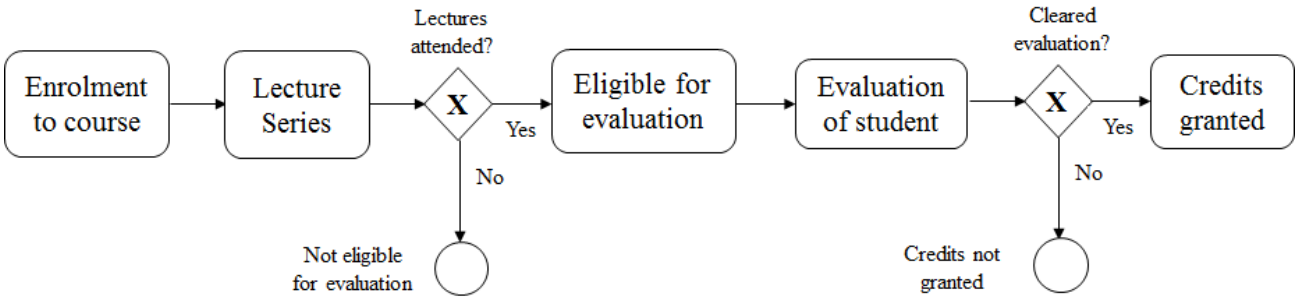

Figure 3. A simplified example of enrolment, evaluation and credit earned using Business Process Model and Notation (BPMN) diagram

Certain subjective and objective factors lead to poor learning outcomes from a student's perspective such as the lack of willingness to learn and/or financial issues.Blockchain can implement a policy of learning is earning thus motivating students (Sharples & Domingue, 2016). Smart contracts can be applied between students and teachers as shared earlier in figure 2. Earning can be provided using real-time awards to the students through simple tasks and clicks by the instructors. Digital currency can be thus earned by students using smart contracts as rewards. Education wallets can be created with this amount collected by the students and can be consumed towards payment of tuition fees as also for exchanging with real money.

Due to the difficulties in the tracking of each and every detail in teaching and learning, makes formative assessment difficult thus creating a problem in evaluation in an education system. Smart contract and Blockchain can tackle this challenge. Due to the characteristics of Blockchain like immutability, traceability, and reliability the data recorded is specific and authentic, tamperproof and trustworthy.It results in collaborative learning and cultivates the ability among students' to work with each other. However, an important challenge in this matter is of free-riding that leads to unfair evaluation.Blockchainshelp in successfully lessen this challenge. In such cases, submission of work by the student is done using a public and private key with a unique identity and the submission is reviewed by the smart contract and the results are recorded in blocks. These records show the entire collaborative learning of the students. Due to the decentralized nature of a public Blockchain, fairness in the evaluation process is ensured.

From a teacher's perspective, the instruction is refined and creative in order but it's tough to evaluate. The standard methodology supports students' feedback and hence islopsided. It is not very useful for a teacher's improvement as it also lacking subjectivity. A brand new system of assessment can be made based on smart contract and Blockchain network.Preplanned educational activities have to be submitted to the institute as a smart contract. The procedure starts with the submission of planned learning activities along with instructions by the teachers to the university. The Blockchain network records all these teaching activities in the Blockchain network.The consistency in the teaching method proposed and actually delivered is an important indicator of instruction analysis and can be verified by smart contract. Also in line with the same, more smart contractscan be created between teachers and students' additional to the one between teachers and college. Teacher's meeting the required obligations receive digital currency as a reward thus appreciating and recognizing the teacher'sabilities.

From the student's development perspective, the supervisor is responsible for monitoring the student's program. They are also responsible for helping in designing study programs and keeping abreast with the analysis and progress of students.Inreality, however, these issues may not have been given their due which will make it difficult to make people accountable if problems arise in the future.Smart contracts and Blockchain can be the answer to this issue.The smart contract should monitor all details like a number of times a supervisor discusses with a student in one semester, a number of times a supervisor takes a review of the thesis, appropriate help offered to students to select courses etc.and also record this information in the ledger of the Blockchain. Such pioneering applications will provide protection to the interests of all stakeholders.

Measuring the learning method and its outcomes in an effective and efficient way can be achieved using Blockchain. Blockchain provides proof of value to all the stakeholders in a reliable manner. Decentralization and immutability enable the Blockchain to solve the issues of data spatiality and trust between strangers.

Data authenticity and its true are ensured by the Blockchain and distributed equally among all the users of the network. Blockchain also serves as a dependable platform for investing in talent. The consumerswho are better educated on digital currencies have a higher probability to succeed in investments. The entire learning can be tracked in the Blockchain ledger. This data can be used by prospective employers to offer roles that match skills. This will decrease the possibility of human resource investment bias and failure.Blockchain maximizes benefit to all stakeholders.

3.4.POTENTIAL ISSUES INTHE APPLICATION OFBLOCKCHAIN TECHNOLOGY IN EDUCATION

Some potential drawbacks exist in applying Blockchain technology to education. It is not possible to evaluate class presentations and written articles like essays through a pre-programmed system without any human interference. Certain learning procedures and the outcomes based on them need to be examined subjectively by the supervisors. If an educational institution implements the Blockchain system then all the knowledge acquired by students and their evaluations will be integrated into the Blockchain. As a result of the feature of the immutability of the Blockchain ledger, the system will not permit any changes in case a modification of instructional records even for justified reasons.Subjective evaluation of certain learning procedures followed by the students and the subsequent learning outcomes like presentations and essays makes the system complex in nature. Apart fromthese issues, other areas involving technicalities of the teaching pedagogies and evaluation mechanisms also need to deal with utmost caution to negate the subjectivity present in the education system. Considering proof of work mechanism which is based on the consensus will lead to haphazard management in turn leading to poor performance in a number of transactions (Vukolić, 2015) and this might lead to an additional expense, and challenges in the application of Blockchainin education.

4. CONCLUSION

To conclude, Blockchaintechnology usesdistributed ledgers prepared on consensus algorithms encrypted using cryptography which together leads to immutability, decentralization, trust, traceability and money properties. The currency properties of this technology initiate many inventive and potential applications for the education sector. Based on the concept shared in an earlier section, Blockchain technology aides in student wisdom and motivations. Records of educational activities and outcomes are stored in a trustworthy manner considering both the formal as well as informal learning environments. Teacher's records relating to the behaviour and performance are also maintained thus helping in teaching evaluation. Both the parties, the learners and teachers have access to the information and the processes followed during the curriculum.

For the researchers, the potential of Blockchain technology can be explored and applied in the education arena. The research in this area is far and few. Topics related to credit transfer, formal and informal learning outcomes can be studied further.

Smart contracts possess important characteristics and benefits for educators and thus provide lucrative opportunities to adopt Blockchain technology. The smart contract ensures the learning activities are verifiable, robust, and traceable. Furthermore, the institutes, colleges and universities must be ready to embrace the ever-expanding scope of Blockchain technology.

DECLARATIONS

Availability of data and materials: The paper provides conceptual framework on the stated subject matter and does not have additional data and materials.

Funding: The authors did not receive any funding for the work undertaken.

Acknowledgements: We would like to acknowledge our respective affiliating institutions for providing us with the support.

REFERENCES

1. Azaria, A., Ekblaw, A., Vieira, T., & Lippman, A. (2016). Medrec: Using blockchain for medical data access and permission management. Open and Big Data (OBD), International Conference On, 25–30. IEEE.
2. Beck, R., Czepluch, J. S., Lollike, N., & Malone, S. (2016). Blockchain-the Gateway to Trust-Free Cryptographic Transactions. ECIS, ResearchPaper153.
3. Bentov, I., Gabizon, A., & Mizrahi, A. (2016). Cryptocurrencies without proof of work. International Conference on Financial Cryptography and Data Security, 142–157. Springer.

4. Bylica, P., Glen, L., Janiuk, P., Skrzypcaz, A., & Zawlocki, A. (2015). A Probabilistic Nanopayment Scheme for Golem.
5. Chen, C. L. P., Wen, G.-X., Liu, Y.-J., & Wang, F.-Y. (2014). Adaptive consensus control for a class of nonlinear multiagent time-delay systems using neural networks. IEEE Transactions on Neural Networks and Learning Systems, 25(6), 1217–1226.
6. Chen, C. L. P., & Zhang, C.-Y. (2014). Data-intensive applications, challenges, techniques and technologies: A survey on Big Data. Information Sciences, 275, 314–347.
7. Chen, G., Xu, B., Lu, M., & Chen, N.-S. (2018). Exploring blockchain technology and its potential applications for education. Smart Learning Environments, 5(1), 1.
8. Czepluch, J. S., Lollike, N. Z., & Malone, S. O. (2015). The use of block chain technology in different application domains. The IT University of Copenhagen, Copenhagen.
9. Desjardins, J. (2016). It's official: Bitcoin was the top performing currency of 2015. Retrieved from The Money Project Website: Http://Money. Visualcapitalist. Com/Its-Official-Bitcoin-Was-the-Topperforming-Currency-of-2015.
10. Devine, P. (2015). Blockchain learning: can crypto-currency methods be appropriated to enhance online learning?
11. Di Ciccio, C., Cecconi, A., Mendling, J., Felix, D., Haas, D., Lilek, D., … Uhlig, P. (2018). Blockchain-based traceability of inter-organisational business processes. International Symposium on Business Modeling and Software Design, 56–68. Springer.
12. Dorri, A., Kanhere, S. S., Jurdak, R., & Gauravaram, P. (2017). Blockchain for IoT security and privacy: The case study of a smart home. Pervasive Computing and Communications Workshops (PerCom Workshops), 2017 IEEE International Conference On, 618–623. IEEE.
13. Fan, J., & YI LT, S. (2013). Research on the technologies of Byzantine system. Journal of Software, 24(6), 1346–1360.
14. Governatori, G., Idelberger, F., Milosevic, Z., Riveret, R., Sartor, G., & Xu, X. (2018). On legal contracts, imperative and declarative smart contracts, and blockchain systems. Artificial Intelligence and Law, 26(4), 377–409.
15. Grech, A., & Camilleri, A. F. (2017). Blockchain in education. Luxembourg: Publications Office of the European Union.
16. Greiner, M., & Wang, H. (2015). Trust-free systems-a new research and design direction to handle trust-issues in P2P systems: the case of Bitcoin.
17. Hammi, M. T., Hammi, B., Bellot, P., & Serhrouchni, A. (2018). Bubbles of Trust: A decentralized blockchain-based authentication system for IoT. Computers & Security, 78, 126–142.
18. Hoy, M. B. (2017). An introduction to the blockchain and its implications for libraries and medicine. Medical Reference Services Quarterly, 36(3), 273–279.
19. Huckle, S., Bhattacharya, R., White, M., & Beloff, N. (2016). Internet of things, blockchain and shared economy applications. Procedia Computer Science, 98, 461–466.
20. Hurich, P. (2016). The virtual is real: An argument for characterizing bitcoins as private property. Banking & Finance Law Review, 31(3), 573.
21. Kosba, A., Miller, A., Shi, E., Wen, Z., & Papamanthou, C. (2016). Hawk: The blockchain model of cryptography and privacy-preserving smart contracts. 2016 IEEE Symposium on Security and Privacy (SP), 839–858. IEEE.
22. Kraft, D. (2016). Difficulty control for blockchain-based consensus systems. Peer-to-Peer Networking and Applications, 9(2), 397–413.
23. Lakshman, T. V, & Agrawala, A. K. (1986). Efficient decentralized consensus protocols. IEEE Transactions on Software Engineering, (5), 600–607.
24. Li, J., Ni, X., & Yuan, Y. (2018). The Reserve Price of Ad Impressions in Multi-Channel Real-Time Bidding Markets. IEEE Transactions on Computational Social Systems, 5(2), 583–592.

25. Li, X., Jiang, P., Chen, T., Luo, X., & Wen, Q. (2017). A survey on the security of blockchain systems. Future Generation Computer Systems.
26. Magazzeni, D., McBurney, P., & Nash, W. (2017). Validation and verification of smart contracts: A research agenda. Computer, 50(9), 50–57.
27. Mougayar, W. (2016). The business blockchain: promise, practice, and application of the next Internet technology. John Wiley & Sons.
28. Nakamoto, S. (2008). Bitcoin: A peer-to-peer electronic cash system.
29. Panarello, A., Tapas, N., Merlino, G., Longo, F., & Puliafito, A. (2018). Blockchain and iot integration: A systematic survey. Sensors, 18(8), 2575.
30. Sharples, M., & Domingue, J. (2016). The blockchain and kudos: A distributed system for educational record, reputation and reward. European Conference on Technology Enhanced Learning, 490–496. Springer.
31. Skiba, D. J. (2017). The potential of Blockchain in education and health care. Nursing Education Perspectives, 38(4), 220–221.
32. Sun, J., Yan, J., & Zhang, K. Z. K. (2016). Blockchain-based sharing services: What blockchain technology can contribute to smart cities. Financial Innovation, 2(1), 26.
33. Swan, M. (2015). Blockchain: Blueprint for a new economy. " O'Reilly Media, Inc."
34. Viriyasitavat, W., & Hoonsopon, D. (2018). Blockchain characteristics and consensus in modern business processes. Journal of Industrial Information Integration.
35. Vukolić, M. (2015). The quest for scalable blockchain fabric: Proof-of-work vs. BFT replication. International Workshop on Open Problems in Network Security, 112–125. Springer.
36. Wang, X., Zheng, X., Zhang, X., Zeng, K., & Wang, F.-Y. (2017). Analysis of Cyber Interactive Behaviors Using Artificial Community and Computational Experiments. IEEE Transactions on Systems, Man, and Cybernetics: Systems, 47(6), 995–1006.
37. Xu, X., Pautasso, C., Zhu, L., Gramoli, V., Ponomarev, A., Tran, A. B., & Chen, S. (2016). The blockchain as a software connector. 2016 13th Working IEEE/IFIP Conference on Software Architecture (WICSA), 182–191. IEEE.
38. Yuan, Y., & Wang, F.-Y. (2016). Blockchain: the state of the art and future trends. Acta Automatica Sinica, 42(4), 481–494.
39. Yuan, Y., & Wang, F.-Y. (2018). Blockchain and cryptocurrencies: Model, techniques, and applications. IEEE Transactions on Systems, Man, and Cybernetics: Systems, 48(9), 1421–1428.
40. Yuan, Y., Wang, F.-Y., & Zeng, D. (2017). Competitive Analysis of Bidding Behavior on Sponsored Search Advertising Markets. IEEE Transactions on Computational Social Systems, 4(3), 179–190.
41. Yuan, Y., Zeng, D., Zhao, H., & Li, L. (2015). Analyzing positioning strategies in sponsored search auctions under CTR-based quality scoring. IEEE Transactions on Systems, Man, and Cybernetics: Systems, 45(4), 688–701.
42. Zhang, J., Xue, N., & Huang, X. (2016). A secure system for pervasive social network-based healthcare. IEEE Access, 4, 9239–9250.