A Proposal on How to Use Blockchain to Secure Communications in 5G Ecosystem

Stephen Mujeye*, Jihad Qaddour, Sameeh Ullah, Susan Calderon, Rob Rhykerd, Charles Edamala, and Fanson Kidwaro

***Abstract*—5G provides businesses with high-speed Internet access, faster bandwidth, and low latency. The use of IoT and 5G-enabled sensors provides new opportunities within networks. There are several use cases of 5G with IoT health care, agriculture, remote learning, logistics, manufacturing, government, and retail. However, some security and privacy problems must be addressed within the 5G ecosystem. There is a need to secure user and device associations and data integrity as 5G is becoming more and more popular. In this research-in-progress, we seek to solve security and privacy problems in 5G by applying Blockchain technology to secure 5G connections. The research will consist of an interdisciplinary team of researchers from Illinois State University (ISU) and non-academic-industry partners. During the study, we build a prototype that solves problems in agriculture and healthcare. A private 5G network is installed at ISU. Moisture sensors and IoT devices are installed at the university farm to monitor soil moisture. Tracking soil moisture helps to conserve water. Additionally, we also work with a local clinic and provide underserved patients with chronic illnesses with sensors and IoT devices that help them track and monitor their chronic conditions. The patients will have monitors that track blood pressure and blood sugar. The IoT devices and sensors send collected data to a database accessible by healthcare professionals at the clinic. This helps the patients receive care that helps them manage their conditions better. Blockchain will be applied during the proposed study to secure communications between the sensors at the university farm and the private 5G network. Blockchain is also be applied to secure communications between the patients and healthcare providers at the clinic. The collected results are analyzed to see if there is a significant difference in suspicious activities in agriculture and healthcare communications. The results have a broader impact, including helping underserved community members to receive good care in managing their chronic conditions. The results also help secure other use cases of 5G with IoT devices.**

***Index Terms*—5G, blockchain, security and privacy, healthcare security, IoT devices, moisture sensors.**

I. Introduction

Having multiple smart devices used by one person would be vital to live a smart life, which would be the 5G revolution touch to our life. 5G also has the potential to balance the inequity in both the inner cities and the rural areas and improve the social mobility of those who are on the wrong side of the digital divide. Consequently, 5G network requirement and capacity will grow significantly because of different applications of 5G. Thus, the network operator must deliver the services to smart users with massive IoT connections, minimal round-trip latency, maximum reliability, and many other features of 5G to support the application needs of the end users. As a solution to fulfill these smart user's needs, a private 5G or local 5G (L5G) is proposed to be deployed as a proof of concept in our university campus as shown in Fig. 1, which allows us to operate our local 5G with unique design and requirements to investigate the needs of our end users to have a smart university campus [1]. L5G was be explored as a major cornerstone to accelerate the implementation of our smart university campus, which includes smart classroom, smart library, smart parking, smart farm that we have for our agriculture department, smart quad and student's activity centers, and smart health and clinic. These concepts will help in further applications that tie in the local community as well as school districts.

However, the deployment of L5G raises serious challenges associated to roaming users, security and privacy, and management of end users, which need to be addressed to meet the end users QoS, Security and privacy, and other application's requirements [2]. Fig. 1 illustrates the local 5G deployed in university campus and local farm. To overcome the above-mentioned challenges, we propose Blockchain as a solution to some of these challenges.

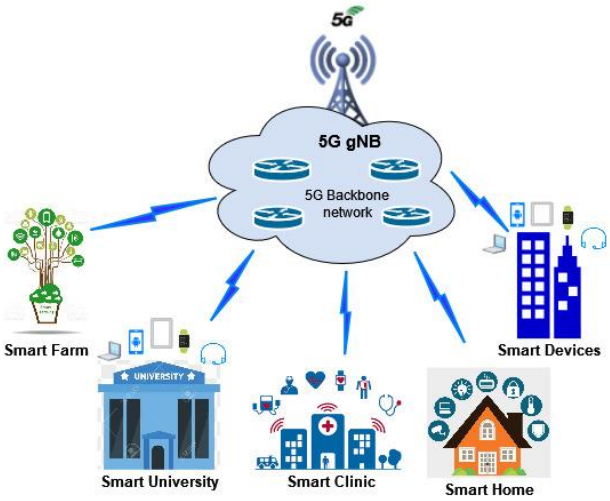

Fig. 1. 5G deployment.

The United Nations (UN) estimates that the global population will increase by 2 billion people from the current 7.8 billion by the year 2050 and that food production may need to increase by 50% or more to feed the worlds growing population [3]. Globally, the most productive lands are already in production and adding more acres to production

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agriculture would destroy fragile ecosystems, contribute further to global climate change, and could accelerate species extension. Additionally, changes in weather patterns associated with climate change may reduce the yield potential from land currently in production. Global climate change has affected precipitation patterns and temperatures in the Midwest. The frequency of intense storms causing flooding and longer periods of drought and higher temperatures has increased water stress on row crop production [4].

Using technology to increase food production on land already in production shows promise to meet future food demands and could help reduce the impacts of climate change. Precision agriculture is an approach to farm management that optimizes profitability, sustainability, and protects the environment. It uses information technology to allow producers to make management decisions and optimize inputs to provide crops with exactly what they need for optimum health and yield productivity, while minimizing and potentially reversing unwanted environmental effects. This study incorporates the use of a smart farming technologies that address these issues and demonstrate how 5G technology can be used to improve precision agriculture.

Healthcare is carefully moving forward to meet the demands in an industry that has been profoundly affected by big data from patient care and its associated organizations. This industry has a high need for safety, risk mitigation, and security, yet it is important that patients remain at the center of care. Consequently, we must find solutions and create innovative technology to address these needs. Empowering the patient to connect and have access to their care from all their providers is not a new idea, what is unique to take advantage of the benefits of a fast network and secure connection by streamlining the patient as a consumer and healthcare as the provider of the services.

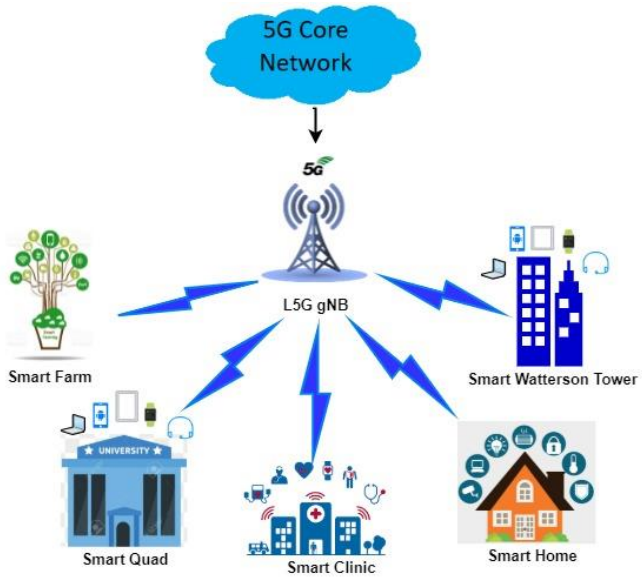

Fig. 2. Proposed 5G network.

This proposed study performs a detailed analysis of the IoT-enabled blockchain 5G network. Blockchain is applied to the 5G ecosystem to help the problems of security, privacy, and scalability. An analysis of how Blockchain helps to improve security, data accountability, and data privacy will be performed. A prototype 5G network is created with the goal of applying Blockchain to include end-to-end confidentiality and data integrity, availability of resources for critical operations, and privacy of the user and device associations. This project seeks to solve agriculture and healthcare problems using 5G and IoT devices, and it consists of use cases and applications in those two areas. Fig. 2 below shows the proposed 5G network with IoT devices. Other applications in manufacturing and transportation will be added.

In this paper, a review of the literature on Blockchain, 5G technology, IoT devices usages in heath care, and smart agriculture is presented. That is followed by the proposed methodology including how data will be collected in the 5G ecosystem. A discussion of anticipated results and the broader impacts of the results follows.

II. Theoretical Background

Blockchain technology (BCT) eliminate the middle and central authority by introducing distributed and decentralized ledger, which will cut cost, add security and privacy, and uplift productivities [5]. Blockchain technology enables users and companies to become parts of a single interconnected network that enables the secure sharing of data. The tamper-proof feature of Blockchain makes it resistant to unlawful changes, and the use of consensus algorithms and smart contracts minimizes the potential of the propagation of fake data and fraudulent information in addition to the immutability within the blockchain records and blocks [6].

BCT adds transactions to the ledger after being validated by miners in the blockchain network instead of a single authorization unit. Moreover, blockchain-based smart contracts can enable distributed and trusted automated services [7]. Due to these properties, Blockchain and smart contacts are utilized in many applications, such as addressing security and privacy issues in different 5G services [8], assurance of trust between mobile operators, and enabling transparency in pre-defined agreements [9], replacement of roaming agreements with smart contracts and elimination of dependent on intermediary parties in the transactions [10], and introducing Blockchain-based solutions to mitigate roaming fraud [11-12] Thus, Blockchain and smart contracts can be a viable solution to resolve many existing implementations and management challenges in our L5G networks [2].

5G is a cornerstone of digital transformation as it represents a significant advancement over previous mobile generation networks. 5G includes high-speed internet access, increased bandwidth, reasonable latency, virtual reality, augmented reality media, UltraHD streaming videos, and many more features. The authors of[13] pointed out that 5G aims to connect the entire world and achieve seamless and ubiquitous communication between anybody, anything, anywhere, anytime, and anyhow. 5G enables new value creation through support for new services based on three major use case domains: enhanced mobile broadband (eMBB), ultra-reliable low latency communication (URLLC), and massive machine-type communications (mMTC) [14]. eMBB provides a high data rate service, low power, and extended coverage with less device complexity via mobile

carriers for IoT applications. URLLC offers low latency, ultra-high reliability, and rich quality of service (QoS), which is not achievable with typical mobile network architecture. URLLC is intended for on-demand real-time interaction such as remote surgery, vehicle-to-vehicle (V2V) communication, industry 4.0, smart grids, and intelligent transportation systems. mMTC enables connection between many devices simultaneously. Investments by national carriers in 5G coverage will accelerate its use in digital deserts in both urban and rural areas.

While 5G and the integration of IoT offer numerous advantages and many possibilities to various industries, it also presents challenges. The challenges include scalability, security, privacy, guaranteeing connectivity of massive IoT devices in a wide range during high mobility, and lack of common standards and protocols. The authors of [15] noted that attackers' capabilities increased by 5G compared to the previous generations. Furthermore, the types of attacks and generated malware are more efficient and effective than those faced by previous generations. The application of Blockchain has been proposed as a solution to the problems and challenges with 5G and the use of IoT devices.

IoT devices are incorporated into healthcare as embedded or wearable sensors on the human body and collect physiological information, including temperature, blood pressure, and electrocardiograph readings [16]. IoT continues to be used in healthcare to transmit data from the patient to the healthcare provider. Researchers pointed out that collecting patient behavioral patterns by installing low-cost sensors in their homes is another use of IoT devices. The information collected can be analyzed to detect anomalies and improve a patient's health.

Additionally, the IoT-based sensors will aid in delivering innovative healthcare by monitoring, detecting, and providing a tool to prevent and manage chronic disease. Moreover, as the Food and Drug Administration has noted, when paired with mobile phone applications, smart devices allow users to monitor and manage their health [16]. Recent surveys indicate that more than 50% of the participants reported positive use for managing their chronic conditions with mobile phone applications [16]. We understand that mobile phone applications (apps) use powerful technology to assist healthcare by delivering non-invasive interventions.

Smart farming involves more than what may be achieved through precision agriculture. According to [17, 18], Smart farming offers a path to sustainability through using of technology. It involves the use of information and communication technologies (ICTs) in the cyber-physical cycle of farm management, with technologies such as IoT and cloud computing, robotics, and artificial intelligence (AI).

III. Methodology

We seek to answer the research question: Can Blockchain's application raise the security and resilience properties of a 5G network? Blockchain technology can be used to detect any changes within the 5G ecosystem. Blockchain aids in allowing different devices to coexist in the same network while providing a high level of security [19]. As a result of analyzing activities using Blockchain, immediate actions can be implemented to prevent security attacks. Based on our prior research, the following hypotheses will guide our study (noted in null layout):

H1 There will be no significant differences in suspicious activities on agricultural devices

H1a There will be no significant differences in the interaction of agricultural communications with the trusted ISU network

H2 There will be no significant differences in suspicious activities on healthcare devices

H2a There will be no significant differences in the interaction of healthcare communications with the trusted ISU network

A. Analysis Tool

BlockSci, a Blockchain analysis tool, analyzes and investigate suspicious activities on IoT devices and other infrastructure in the 5G ecosystem. BlockSci was selected because of its versatility in supporting different blockchains and analysis [20]. The data collected from the 5G network then are analyzed using the multivariate analysis of variance (MANOVA). The MANOVA test will be used in analyzing the hypotheses H1 through H2a. MANOVA is used because of its ability to assess differences in activities.

Therefore, to mitigate challenges encountered in in our L5G system, we propose Blockchain-as-a-Service (BaaS) platform. Many distinct features of BCT are proposed and implemented for this grant such as the security of IoT data of different smart subsystems (smart farm, smart library, smart Quade, and student's activity centers) with the enforcement of decentralized access control through smart contracts, and optimal services to each user to enhance their security and privacy.

The contributions will be summarized as follows:

1) Propose Blockchain-as-a-Service (BaaS) platform to address the key challenges within a L5G systems
2) Propose blockchain-based modularized functions to enable L5G related services efficiently.
3) Evaluate the proposed architecture in a simulated environment.

In this study, we propose a Blockchain-as-a-Service (BaaS) architecture for our private local 5G (L5G) system to overcome each of the potential challenges expected in L5G systems. The BaaS platform is a modularized architecture that comprises several blockchain-based functions. These functions behave as modules, which enables service providers to assemble them based on their diversified requirements and then to produce services and overcome challenges in L5G system and other participants. The proposed BaaS architecture was operated as an overlay entity which is spread across the L5G systems [2].

This Blockchain can be implemented as a consortium blockchain for the BaaS architecture as shown in Fig. 3.

Each participant (i.e., L5G, IoT tenants, smart farm, and others) of the L5G system can participate in maintaining the Blockchain: They can customize and deploy their own blockchain nodes (i.e., miners, full nodes, or light nodes) based on requirements of each participant as shown in Fig. 2. In addition, L5G and participants can be miner nodes which perform mining and peer transactions. For example, the IoT

can operate as miner nodes for IoT, which can be deployed as fog computing nodes whereas the blockchain node in IoT tenants can handle the IoT data management services to share with third-party services via the smart contracts. The main benefit of integrating blockchain nodes to accomplish low latency and perimeter security and privacy of L5G systems of the end users [2].

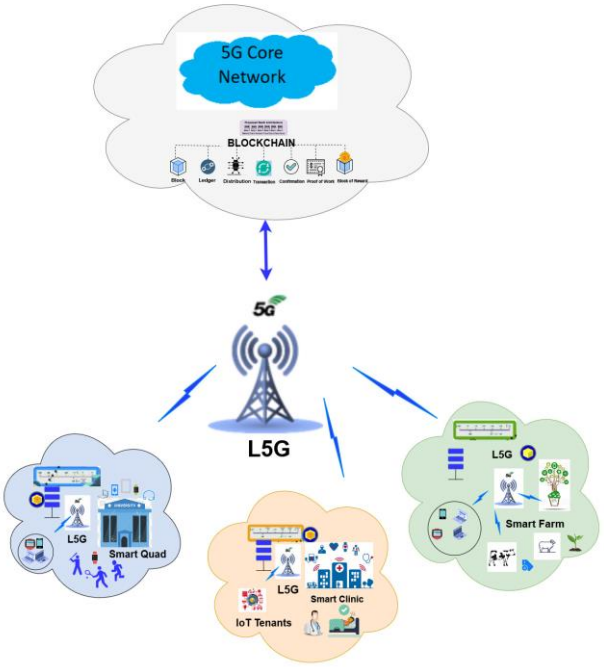

Fig. 3. Blockchain deployment of the BaaS architecture.

IV. Discussions and Conclusions

This study has the goal of using technology to help solve health problems in underserved communities. The population served at the clinic includes patients without insurance and lacking resources to manage their health. With the use of IoT devices and wearable sensors, they will be able to share their vital signs with health care providers who can use that information to improve the health and well-being of patients. The application of machine learning and artificial intelligence will help health care providers to detect problems and put a plan in place before it is too late. The author of [21] proposed a solution that relied on Blockchain as a security mechanism instead of using the public key infrastructure (PKI). By using the Blockchain technology, it would make it difficult for attackers and malicious traffic to make it into the network as it will not be trusted [22]. The proposed network will also include a significant use of IoT devices. The application of Blockchain to secure transactions in IoT devices has been proposed in other sting [23]. We seek to use the same solutions to solve security problems with IoT devicesd used in health care and farming within the 5G network. Ultimately, the health and well-being of patients in underserved communities will be improved.

The results of the study will also help solve the prevalent problems of the depletion of soil nutrients and water conservation. This will produce enough food needed to feed the increasing global population.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

SM wrote the methodology, discussion and conclusion sections and compiled all the contributions from all the authors and formatted the paper. JQ wrote the section about 5G and applying the blockchain technology to the 5G network. SU wrote the sections about blockchain and machine learning. SC wrote the section about healthcare activities. RK wrote the section about smart agriculture. FK wrote the section about agricultural activities. CE contributed to the section about installing and incorporating the 5G private network. All authors approved the final version.

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References

[1] M. M. Blue and M. L. Aho, "Micro operators accelerating 5G deployment," in *Proc. IEEE Int. Conf. Ind. Inf. Syst*., 2017
[2] Werrasnghe *et al*., "A novel blockchain-as-a-service (BaaS) platform for local 5G operators," *IEEE Open Jounranl of Communication Society*, 2021.
[3] United Nations, Department of Economic and Social Affairs, Population Division, World Population Prospects: The 2017 Revision, Volume I: Comprehensive Tables (ST/ESA/SER.A/399), 2017.
[4] Pryor *et al*., "Ch. 18: Midwest. climate change impacts in the United States: The third national climate assessment," U.S. Global Change Research Program, 2012, pp. 418-440.
[5] H. Wang, K. Chen, and D. Xu, "A maturity model for blockchain adoption," Financ. Innov., vol. 2, no. 1, p. 12. 2016.
[6] Z. Zheng, S. Xie, H. Dai, X. Chen, and H. Wang, "An overview of blockchain technology: Architecture, consensus, and future trends," in *Proc. IEEE International Congress Big Data*, pp. 557–564, 2017.
[7] L. W. Cong and Z. He, "Blockchain disruption and smart contracts," *Rev. Financ. Stud*., vol. 32, no. 5, pp. 1754–1797, 2019.
[8] Praveen *et al*., "Blockchain for 5G: A prelude to future telecommunication," *IEEE Network*, vol. 34, no. 6, pp. 106–113, 2020.
[9] V. K. Rathi *et al*., "A blockchain-enabled multi domain edge computing orchestrator," *IEEE Internet Things Mag*., vol. 3, no. 2, pp. 30–36, 2020.
[10] M. Saravanan, S. Behera, and V. Iyer, "Smart contracts in mobile telecom networks," in *Proc. 23rd Annual International Conference Adv. Computing Communinication*, 2017.
[11] C. T. Nguyen *et al*., "Blockchain and stackelberg game model for roam- ing fraud prevention and profit maximization," in *Proc. IEEE Wireless Communication Network Conference*, 2020.
[12] N. Weerasinghe *et al*., "Blockchain-based roaming and offload service plat- form for local 5G operators," in *Proc. IEEE 18th Annual Consum. Communication & Network Conference*, pp. 1–6, 2021.
[13] J. Parikh and A. Basu, "Technologies assisting the paradigm shift from 4G to 5G," *Wireless Personal Communications*, 2020.
[14] A. Ghosh, M. Maeder, and D. Chandramouli, "5G evolution: A view on 5G cellular technology beyond 3GPP release 15," *IEEE Access*, 2019, pp. 127639-127651.
[15] B. A. Sullivan, S. A. P. Kumar, and M. Conti, "5G security challenges and solutions: A review by OSI layers," *IEEE Access*, 2021, pp. 116294–116314.
[16] B. Pradhan, S. Bhattacharyya, and K. Pal, "IoT-based applications in healthcare devices," *Journal of Healthcare Engineering*, 2021.
[17] J. Yang, G. Lan, Y. Li, Y. Gong, Z. Zhang, and S. Ercisli, "Data quality assessment and analysis for pest identification in smart agriculture," *Computers and Electrical Engineering*, vol. 103, 2022.
[18] G. Fortino, F. Gabriele, and C. Savaglio, "A low-cost smart farming prototype with internet of things (IOT) technologies and edge computing devices," in *Proc. 2021 IEEE Intl Conf on Dependable, Autonomic and Secure Computing*, 2021.
[19] F. Gao *et al*., "Revealing development trends in blockchain-based 5G network technologies through patent analysis," *Sustainability*, vol. 13, no. 5, 2021.

[20] H. Kalodner *et al*., "Design and applications of a blockchain analysis platform," in *Proc. Proceedings of the 29th USENIX Security Symposium*, pp. 2721-2738, 2020.
[21] E. F. Kfoury and D. J. Khoury, "Secure-end-to-end VoIP system based on Ethereum blockchain," *Journal of Communications*, vol. 13. no. 8, pp. 450-455, 2018.
[22] A. Mostafa, "VANET Blockchain: A general framework for detecting malicious vehicles," *Journal of Communications*, vol 14, no 5. pp 356-362, 2019.
[23] A. H. Ahmed, N. M. Omar, and H. M. Ibrahim, "Performance evaluation of a secured framework for IoT based on blockchain," *Journal of Communications*, vol 17, no. 1. pp. 1-10, 2022.

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Fanson Kidwaro is a chair of Department of Agriculture at Illinois State University. Dr. Kidwaro was previously the chair of Biology and Agriculture at University of Central Missouri for eight years before joining ISU. Kidwaro has been teaching diverse Agronomy courses since 2001 and conducts research in Nutrient Management, Sustainable Agriculture and Alternative Energy, such as using Switchgrass for cellulosic ethanol. He has taught about the use of precision agriculture in modern agronomic practice for better management of resources. Kidwaro is interested in using technology to improve sustainability and profitability in agriculture.