Block Chain Technology for Gun Reform: Evaluating the ATF's Database Challenges

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ABSTRACT
Firearm-related violence is the leading cause of death among children and teens in the U.S., yet effective solutions remain elusive due to political and logistical challenges. I propose a computer science-based solution: modernizing the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF) firearm tracking system using blockchain technology. This would create an immutable, secure, and efficient database to streamline firearm sales documentation, enhance law enforcement resources, and ensure privacy for gun owners. The proposed system incorporates a permission based blockchain featuring encrypted nodes and smart contracts to automate compliance, track transactions, and integrate with existing ATF workflows. Results from this pilot program will determine the system's effectiveness in addressing delays and inefficiencies in firearm tracking. Future work includes scaling the system to a national level, refining privacy and security measures, addressing potential integration challenges and encouraging continuous updates to the system to ensure efficient and effective databases.

1. INTRODUCTION

The leading cause of death among children and teens in the U.S. is firearms (Villarreal, et al., 2024). Despite widespread recognition of this issue, political resistance has hindered meaningful action. The NRA opposes gun control measures, arguing they infringe on law-abiding citizens' rights (National Riffle Association, n.d.). However, initiatives like the 2022 Bipartisan Safer Communities Act have attempted to curb illegal gun sales by strengthening ATF oversight (United States Department of Justice, 2024). Additionally, technologies such as SmartGuns and ShotSpotter have been developed, but their high costs and enforcement challenges limit effectiveness. A key issue in reducing gun violence is the outdated firearm tracking system. Since 1986, federal law has prohibited the ATF from maintaining a digital gun registry (Moone, 2023). This has resulted in the reliance on inefficient paper records. Given that 15.9 million firearms were sold in 2023 (Cassidy, 2024), a modernized tracking system is essential.

2. RELATED WORKS

The Center for American Progress's 2020 report emphasizes the need such gun tracking technology, especially in the wake of so many mass shootings. Their report critically examines the ATF's budget allocations from 2013 to 2020. The analysis reveals that the ATF has disproportionately allocated resources to reactive law enforcement activities, such as addressing "firearms criminal use and possession" and "combating criminal organizations." Funding for these areas increased from 36% of the law enforcement operations budget in 2013 to 54% in 2020 (Parsons, 2020).

On the other hand, investment in proactive measures like "deterring illegal firearms trafficking" and preventing the "diversion of firearms from legal commerce" remained stagnant, comprising only 24% to 27% of the budget during the same period. This lack of budgetary focus introduces the risk that the ATF

and local agencies may be focusing on redundant initiatives. The report advocates for a strategic reallocation of ATF's budget to emphasize its unique capabilities, such as investigating interstate gun trafficking and providing specialized support to local law enforcement through gun tracing and ballistics matching technologies. By prioritizing these areas, ATF can enhance its effectiveness in reducing gun violence and better fulfill its regulatory role over the firearms industry (Parsons, 2020).

The above evaluation introduced the importance of finding a secure and effective digital method of tracing guns. I propose a blockchain technology system seen in many other sectors of society such as healthcare. Blockchain technology has gained significant attention due to its ability to improve security, data integrity, and transparency, particularly in managing sensitive information.

A review by Saeed, et al. (2022) highlights how Blockchain has transformed healthcare by enhancing efficiency, data privacy, and access control. By utilizing a decentralized approach, Blockchain offers a secure means of managing clinical records and personal medical information. The same principles can be applied to the firearms sector, where tracking and verifying firearm ownership, sales, and transfers can be securely stored via Blockchain. The review also discusses the potential for Blockchain to address data protection and regulatory challenges, which are crucial elements when considering healthcare legislation and firearm legislation alike. Integrating blockchain technology into firearm tracking could introduce a new era of digital security and traceability, paralleling its positive impact on healthcare systems.

3. PROPOSAL DESIGN

My project will focus on modernizing the ATF database system through the implementation of blockchain technology to create immutable digital records for firearm sales. This program will include automated compliance, resources for law enforcement and increased privacy for gun owners through its intricate blockchain infrastructure. Blockchain technology is by nature trustworthy and private, with the ability to track important information about firearm transactions.

IBM (2024) defines blockchain as “ideal for delivering information because it provides immediate, shared, and observable information that is stored on an immutable ledger that only permissioned network members can access” Blockchain also allows for decentralization, meaning that no single entity has complete control over the database, reducing the risk of tampering or unauthorized modifications. Each transaction recorded on the blockchain is cryptographically secured, ensuring data integrity and making it nearly impossible to alter past records without consensus from the network. Additionally, smart contracts can be integrated into the system to automate compliance with firearm regulations, streamlining processes such as background checks and sales verification. These contracts can enforce legal requirements in real-time, reducing the administrative burden and improving accuracy (IBM, n.d.)

Another key benefit of using blockchain for the ATF database is its potential to enhance privacy while maintaining traceability. Gun owners' personal data can be encrypted, ensuring that only authorized parties, such as law enforcement agencies with proper clearance, can access transaction details when necessary. This balance between transparency and privacy addresses concerns about government overreach while still providing a secure and auditable record of firearm transfers.

The first step of this project would be to develop the technology specifically for firearm sales. Through working alongside several cybersecurity professionals and experienced blockchain developers, the team would design a secure blockchain tailored to the ATF’s needs. This blockchain system would include encrypted nodes and smart contracts capable of validating compliance data, with strict privacy measures to protect sensitive information. The initial prototype would focus on functionality such as transaction tracking, data entry for background checks, and automated compliance checks, all designed to integrate seamlessly with the ATF’s existing workflows. Seen in Figure 1 is an example diagram of how this technology would work based on the diagram provided by Monrat, et al in their 2019 blockchain study.

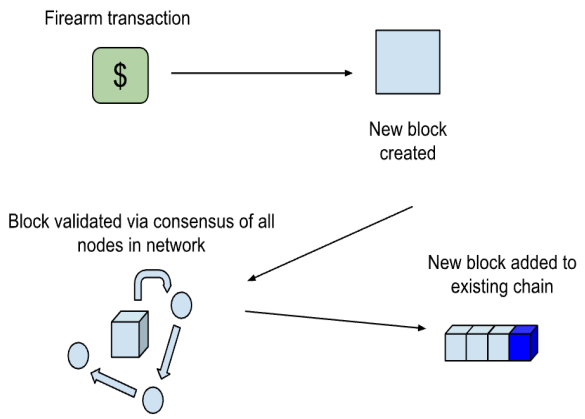

Figure 1: Diagram of the Blockchain Process

The next step of the project would involve testing the technology out on a small network of licensed firearm providers. This pilot program would allow the selected firearm providers to input important data such as the gun owner's 4473 form, background checks, date of purchase, and type of weapon purchased at the time of a sale. Each firearm sale transaction would be logged as a block containing encrypted details about the buyer, the firearm purchased, and the seller's credentials. These transactions would be validated using a consensus mechanism, preventing any single entity from making unauthorized modifications. Furthermore, smart contracts would automatically verify compliance with ATF regulations, ensuring that a firearm cannot be sold to an ineligible buyer. For instance, if a background check returns a denial, the smart contract would prevent the sale from being recorded and alert the appropriate authorities.

The pilot program would also include real-time auditing capabilities for law enforcement agencies. Only authorized personnel with the proper security keys would be able to trace firearm transactions, reducing the likelihood of illegal firearm sales while maintaining the privacy of responsible gun owners. To ensure accessibility, the blockchain interface would include a secure portal for firearm dealers, allowing them to input transaction details quickly and efficiently. The pilot program would test the scalability of the blockchain system, ensuring it can handle a growing number of transactions without performance issues. Security assessments, including penetration testing and vulnerability analysis, would be conducted in collaboration with cybersecurity professionals to address potential threats before scaling up.

If this setup proves to be successful for the small cohort of firearm providers, the next phase would involve collaborating with the ATF to expand the system nationwide. This would require integrating blockchain infrastructure with existing federal and state databases, ensuring interoperability and compliance with legal standards. At this stage, further refinements would be made to optimize transaction speed, user accessibility, and law enforcement oversight mechanisms before full deployment to licensed dealers across the country.

4. ANTICIPATED RESULTS

After evaluating the proposed plan for implementing a blockchain-based digital record system, the expected outcomes of this project are as follows. First, if the rollout program is successful, a digital record system will be implemented across all authorized gun sellers' systems. This will result in a major advance in gun tracking and public safety. Through these digital systems, law enforcement will have the ability to rapidly track illegal weapons and retrieve information on weapons used in violent crime. Additionally, this will create a much more efficient ATF, allowing them to turn their attention towards other initiatives such as firearm safety and training. Secondly, if the blockchain system proves to be scalable and effective, the ATF can begin enforcing and implementing it in smaller gun sellers' operations. Ensuring that all gun sellers adopt the same digital tracking system will be challenging, but it will yield significant benefits, not only financially but also in terms of safety and efficiency.

Beyond these direct results, the overarching impact of the blockchain-based gun tracing system extends to broader societal and governmental improvements. By establishing a standardized and transparent digital record system, this initiative can strengthen public trust in firearm regulations and enforcement. The enhanced ability to track and monitor firearms can serve as a deterrent to illegal gun sales, contributing to a reduction in gun-related crimes over time. Additionally, the efficiency gains within the ATF and other law enforcement agencies may lead to better resource allocation,

allowing for more proactive measures in crime prevention and public safety. Ultimately, this system has the potential to create a more accountable and secure firearm marketplace while reinforcing the balance between responsible gun ownership and effective regulatory oversight.

5. CONCLUSION

The persistent challenge of firearm-related violence in the United States demands innovative, non-partisan approaches that prioritize public safety while respecting individual rights. I propose a technologically-grounded solution to one of the ATF's most pressing limitations: its outdated, paper-based firearm tracking system. By introducing blockchain technology into the firearm sales documentation and tracking process, this system presents a secure, immutable and transparent alternative that enhances law enforcement capabilities and streamlines compliance processes while protecting the privacy of responsible gun owners.

The proposed blockchain-based solution stands to significantly modernize the ATF's operations, offering real-time access to firearm transaction data for authorized personnel and enabling smart contract-based automation for regulatory compliance. The potential societal impact of such a system is substantial, from deterring illegal firearm sales to enabling faster and more effective criminal investigations. Furthermore, this project highlights the broader applicability of emerging technologies like blockchain in public policy and regulatory contexts, demonstrating how computer science can contribute to solutions for complex social issues.

6. FUTURE WORK

To bring this proposal to full implementation, several critical next steps must be addressed. First, the pilot program must be developed and rigorously tested in partnership with a controlled group of licensed firearm dealers and cybersecurity experts. This phase will help identify technical, legal and logistical challenges, especially those related to integration with existing state and federal databases.

Once functionality, security and compliance are verified, efforts should focus on scaling the system nationally, requiring collaboration with government stakeholders, the firearm industry, and privacy advocates. Additionally, future iterations of the system should incorporate adaptive features, such as AI-powered analytics for threat detection and tools for anonymized data sharing in academic and policy research. Continuous updates to the platform will be necessary to address evolving regulatory requirements, technological advances and cybersecurity threats.

As blockchain technology matures, the system may also be extended to other aspects of gun regulation, such as monitoring manufacturer distribution channels or facilitating cross-state firearm tracing. Ultimately, sustained interdisciplinary collaboration will be key to realizing the full promise of this proposal.

REFERENCES

Cassidy, D. (2024, January 8). Americans charted record book year for firearms in 2023, with 2024 looming large too. *NSSF.* https://www.nssf.org/articles/2023-record-year-for-firearms-2024-looming-large/

Justice.gov. (2024, June 25). Fact sheet: Two years of the Bipartisan Safer Communities Act. *Office of Public Affairs* | United States Department of Justice. https://www.justice.gov/archives/opa/pr/fact-sheet-two-years-bipartisan-safer-communities-act

IBM. (2024, August 28). What is blockchain?. *IBM.* https://www.ibm.com/think/topics/blockchain

IBM. (n.d.). *What are smart contracts on blockchain? IBM.* .https://www.ibm.com/think/topics/smart-contracts

Mone, J. (2023, March 28). ATF handcuffed by archaic records system. *Scripps News*

Monrat, A., Schelén, O., & Andersson, K. (2019). *A survey of blockchain from the perspectives of applications,challenges, and opportunities*.LTU.https://doaj.org/article/97d8965c0f564c0691fb570a92ce7b56

National Rifle Association. *NRA statement on gun control package*. National Rifle Association. https://home.nra.org/statements/nra-statement-on-gun-control-

p a c k a g e / #:~:text=This%20gun%20control%20package%20will,curb%20violence%20across%20our%20country.

Parsons, C., Weigend Vargas, E., & Bhatia, R (2020, September 17). *Rethinking ATF's budget to prioritize effective gun violence prevention.* Center for American Progress. https://www.americanprogress.org/wp-content/uploads/sites/2/2020/09/ATF-Budget-Analysis.pdf

Saeed H, Malik H, Bashir U, Ahmad A, Riaz S, Ilyas M. (2022) Blockchain technology in healthcare: A systematic review. PLoS ONE 17(4): e0266462. https://doi.org/10.1371/journal.pone.0266462

Villarreal, S., Kim, R., Wagner, E., Somayaji, N., Davis, A., & Crifasi, C. (2024). Guns remain the leading cause of death for children and teens. *Johns Hopkins Bloomberg School of* Public Health. https://publichealth.jhu.edu/2024/guns-remain-leading-cause-of-death-for-children-and-teens

NBC Universal News Group. (2022, August 22). ATF now needs 2 weeks to perform a routine gun trace. *NBCNews.com*. https://www.nbcnews.com/news/s-just-insanity-atf-now-needs-2-weeks-perform-routine-gun-trace-rcna3966