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BirthChain: a blockchain platform for birth certificates

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Blockchain is the evolving technology used by government and private organizations to empower themselves by digitizing and automating their work with the help of distributed computing and cryptography. This technology is being adopted by numerous application areas, including land registry, notarization, civil registration system, and digital certification. In this article, a blockchain-based platform called BirthChain is proposed for digitizing the birth certificate generation and distribution process. Hospitals will use this platform to provide data on newborns, which will be validated by the municipal corporations. The birth certificates will be automatically generated and emailed to the parents in addition to the existing process of certificate generation and handling. The platform will streamline the current birth certificate generation process, remove delays, and provide a secure digital platform. BirthChain has been implemented using Ethereum's Remix IDE. BirthChain is validated by discussing its implementation on various Ethereum Virtual Machine (EVM)-compatible blockchain networks and comparing it to the existing birth certificate generation process.

KEYWORDS

birth certificate, BirthChain, blockchain, EVM-compatible smart contract, Remix IDE, smart contract, Solidity

1 Introduction

Blockchain (Sapra and Dhaliwal, 2021a) is a distributed technology that came into existence in 2008 through Bitcoin (Franco, 2014). The technology has become increasingly popular and accepted in many application areas in recent years. Blockchain is a combination of previously existing cryptography and distributed computing technologies. The records or data are cryptographically stored, which maintains the integrity of the data and also provides confidentiality. The data or the transactions are digitally signed by the sender and receiver, providing non-repudiation of data or information so that later, neither the sender nor the receiver can deny it.

In blockchain technology, the data are stored in blocks. Every blockchain system has a defined block size. The first block in any blockchain system is called a genesis block (Niranjanamurthy et al., 2019). The genesis block acts as the starting point for every blockchain system and is usually referred to as Block 0. Every block includes two parts: a block header and a set of transactions. The block header has four major components: a timestamp, a nonce, a root hash, and a previous block root hash. The timestamp is the time of the creation of the block. The nonce is the special numerical value that is required by the miners as a result of their hash from the block. A root hash, also called the Merkle root

(Sapra and Dhaliwal, 2018), is evaluated by combining the hashes of all the transactions in the block. The block also stores the Merkle root of the previous block. This connects one block to another, and hence all the blocks of blockchain form a chain of blocks by connecting with the previous block's root hash. This makes the block immutable. Even if there is a change made by an intruder in any transaction of a block, its root hash will change, which must be revised in its next block. So, one can easily identify any forgery of data in the blockchain.

The transaction processing, verification, block creation, and storage are all done in a distributed manner. There is no single point of failure, as a complete copy of the blockchain system is stored at multiple locations with miner nodes and full nodes. This makes the blockchain system robust and breakdown-free. In addition, the blockchain system runs 24 × 7, as the transactions happen online. The data are stored in the form of cryptographic hashes, which protect them against manipulation by intruders. All these features of blockchain make it secure and useful for various applications in improving their existing processes.

The process of birth certificate registration and generation is very time consuming. A birth certificate (Wikipedia, 2021) is the first authenticated document of a child. It is required at multiple instances during his/her life. It acts as proof of one's age and is a mandatory document required for admission to school, to apply for a passport or immigration, or to obtain citizenship of the country, etc. In India, birth certificates are generated by the municipal corporations in urban areas. In rural areas, these certificates are generated by the gram panchayat office or through the tehsildar. To apply for the child's birth certificate, one must complete the registration form provided by the municipal authority and submit it along with the other documents within 21 days of the child's birth. If this process is not done within 21 days, police verification and a late fee are mandatory for the registration of the birth certificate. Once the form is filled, the records are verified by officials, who then issue the certificate.

The birth certificate registration form is also available online through the Civil Registration System (Crsorgi, 2021) in limited parts of the country. Anyone who completes the online registration form must then print and submit it by hand to the concerned municipal authority. The current process of birth certificate registration, either online or offline, requires the parent to visit the office at least 2–3 times. Apart from this, there might be unnecessary delays if an officer is not available or is on leave. To simplify this process, a novel blockchain system called BirthChain has been proposed for the registration, generation, and disbursement of birth certificates. In this system, all the newborns will be directly registered digitally on the blockchain platform. All the details of the newborn and his/her parents will be provided by the hospital directly. These details will be signed digitally by the hospital authority. Municipal authorities will receive notifications about the newborn and the necessary documents through the blockchain platform. Once the municipal committee validates the information, the child's birth certificate will be automatically generated and emailed to the parents. A digital copy of the certificate will always be available through the network without any possibility of being misplaced.

The main objective of this article is to propose BirthChain, a blockchain-based secure platform for the registration and generation of birth certificates. This platform will ease the work for parents and municipal authorities. The application will remove unnecessary paperwork and delays in the process. This article will be beneficial for students, researchers, and academicians working in the field of blockchain technology who want to either pursue research or implement blockchain in diverse domains.

An introduction to the concepts and workings of blockchain technology is provided in Section 2, which also discusses the very important features of blockchain technology that make it useful for different applications. Then, various existing application areas using blockchain technology are discussed in Section 3. In Section 4, we discuss the proposed BirthChain blockchain system, giving a detailed explanation of the architecture, smart contract, and various modules. Finally, in Section 5, we summarize the article and discuss the scope for future research.

2 Background

A blockchain network is a network of participants (Sapra and Dhaliwal, 2021a). The participants in the blockchain network are called the nodes of the blockchain. Some nodes only perform read transactions. These are called simple nodes of the network. The nodes that keep a copy of the blockchain system, including the set of all transactions that happened in time, are called the full nodes of the network. There are multiple full nodes within a blockchain network. Full nodes verify transactions in the network. Apart from simple and full nodes, there are various miner nodes in the network that create blocks and append them to the existing blockchain.

Nodes of the blockchain network are allowed to read, write, or mine the transactions, depending on the type of the blockchain network. In public blockchain networks like Bitcoin (Franco, 2014) and Ethereum (Metcalfe, 2020), any node can mine, view, or perform transactions without any prior permission. This is called a permissionless blockchain network. In contrast, permissioned blockchain networks like HyperLedger Fabric (Cachin, 2016) or Corda (Valenta and Sandner, 2017) have an access control layer that defines the role of the participating nodes. The identity of nodes is known, and there are restrictions on who can join the network, perform transactions, or mine the block. Private blockchain networks are restricted to an organization, and if networks that are restricted to a set of organizations are called federated or consortium blockchain networks.

The blocks in the blockchain system are added through the process of mining. Mining involves verification of the transactions done by the nodes of the network through the full nodes (Sapra and Dhaliwal, 2021b). After transactions are verified, miners write the hashed transactions to the block and evaluate the Merkle root and nonce. The mining process ends after the successful addition of the block to the blockchain. Miners are generally rewarded with some cryptocurrency. Numerous miners in a blockchain network compete to evaluate the nonce first.

Blockchain has evolved progressively in different generations (Xu et al., 2019). The Blockchain 1.0 (Swan, 2015) era was the initial era when blockchain was limited to financial applications through cryptocurrency. There are more than 5,000 cryptocurrencies (Coinlore, 2021) available for trading in the market. These cryptocurrencies were built one after the other. Some of the popular cryptocurrencies are Bitcoin (Franco, 2014), Ethereum (Metcalfe, 2020), Litecoin (Padmavathi and Suresh, 2019), and Ripple (Schwartz et al., 2014) During this time, blockchain was only used for peer-to-peer financial transfers using distributed computing.

Blockchain 2.0 (Ulieru, 2016) included decentralized applications through smart contracts (Zou et al., 2019). Ethereum (Metcalfe, 2020) was the first blockchain platform to introduce smart contracts. HyperLedger (Cachin, 2016), Quorum (Polge et al., 2020), and RSK (Li et al., 2020) are some of the other smart contract generation platforms. Most applications in Blockchain 2.0 were limited to financial applications. During this time, blockchain was used as a service (BaaS), and this encouraged various corporations and organizations to try blockchain for their operations. This led to the development of various consensus protocols (Sapra and Dhaliwal, 2020a) like Proof of Stake (PoS) (Sapra and Dhaliwal, 2020b) and Delegated Proof of Stake (DPoS) (Yang et al., 2019) to improve the efficiency and resource utilization of the blockchain system.

Blockchain 3.0 involves a variety of applications other than the financial domain, such as health, media, and science (Maesa and Mori, 2020). These application areas involve smart contracts as a part of their application. These smart contracts are small programs or lines of code that execute whenever a particular condition happens. They make the blockchain system work automatically. Ethereum (Metcalfe, 2020) introduced the concept of a programmable blockchain. The concept of a smart contract has made it useful in a wide variety of applications, such as supply chain management, healthcare, and voting systems. The contract is auto-enforceable, as it executes itself whenever the defined condition is met. Numerous application areas utilize blockchain technology to improve their working processes and the security of their applications.

3 Related work

Blockchain is a distributed computing technology that involves cryptography and an append-only mode to provide security and privacy of data (Sapra and Dhaliwal, 2021a). Within the last decade, the number of applications involving blockchain technology has increased dramatically. The technology is becoming acceptable in every field of work. It started with Bitcoin (Franco, 2014) as a financial application. In the beginning, there were controversies regarding the acceptance of the technology, but with new application areas evolving, the technology is becoming accepted in a wide variety of application areas.

In the financial sector, blockchain is used to handle security and privacy concerns. It is used in insurance (Zhou et al., 2018; Naminova et al., 2020; Aleksieva et al., 2020; VanderLinden, 2018), the stock market (Lee, 2015; Ba et al., 2019; Lo et al., 2017), mobile payments (Shrivastva et al., 2020), cross-border payments (Liao and Shao, 2021; Shrivastva et al., 2020; Belouafi, 2021), real estate (Spielman, 2016; Sanka et al., 2021; Van Hijfte, 2020; Latifi et al., 2019; Khanna et al., 2020), and banking (Hassani et al., 2018; Belu, 2019; Civelek and Özalp, 2018). MIStore (Zhou et al., 2018) is an Ethereum-based blockchain platform for medical insurance for patients, hospitals, and insurance providers. The patient's data are securely stored by hospital administration on the blockchain ledger for easy and effortless insurance payments. Teambrella is another blockchain application for insurance providers and claimers for resolving disputes regarding insurance claims and reimbursements (Naminova et al., 2020). This platform uses peer voting for decision-making and blockchain for payments. Etherisc is a decentralized application for insurance that aims to reduce the claim processing time and costs through blockchain (Aleksieva et al., 2020). Friendsurance is another insurance provider that uses the blockchain's peer-to-peer technology to bring transparency and affordability to the customers of insurance (VanderLinden, 2018).

In the stock market and trading, several real applications are being used for maintaining security and privacy in the financial world (Lee, 2015). A secure blockchain model (Ba et al., 2019) uses machine learning with blockchain for an intelligent prediction system for the stock market to predict future stock prices. Nasdaq (Lo et al., 2017) is using Linq (Lo et al., 2017) blockchain to reduce the transaction time and settlement issues. Blockchain has also been successful in enabling electronic money transfers within the country or across countries (Liu and Li, 2020). BitPay (Liao and Shao, 2021) is a payment gateway to transact in terms of cryptocurrencies, Bitcoin, or Bitcoin Cash for businesses in the world. Koinex (Shrivastva et al., 2020) is another cross-border payment platform for blockchain-based digital payment processing. PumaPay (Belouafi, 2021) uses blockchain technology for its payment processing while allowing credit cards as a mode of payment. Hundreds of businesses have integrated with PumaPay to ease their payment systems.

Blockchain technology has many use cases in the real estate industry for asset management, land registry, and transfers (Spielman, 2016). A framework (Sanka et al., 2021) has been designed using an Ethereum smart contract between the real estate owners and customers to provide a user-friendly system for the sale and purchase of properties. PropertyClub (Van Hijfte, 2020) provides a blockchain-based platform for the sale and purchase of properties and allows for digital payments through cryptocurrencies, including PropertyClub Coin (PCC) and Bitcoin. SMARTRealty (Latifi et al., 2019) is a blockchain-based platform for real estate purchase and rental agreements that establishes smart contracts between the two parties. The Bee Token (Khanna et al., 2020) is a home-sharing platform that uses blockchain for renting the property, and the payments for the same are done digitally via cryptocurrencies.

In the banking sector, blockchain technology is used for faster transaction processing, digital identity verification, fundraising, loans, and much more (Hassani et al., 2018). WeTrade (Belu, 2019) was developed and maintained by IBM for financial transfers among companies internationally to remove any third-party interference and uses smart contracts to avoid any risks. Marco Polo (Civelek and Özalp, 2018) is a blockchain-based finance network that connects banks, corporates, and other financial institutions for seamless transfers among its participants. All the

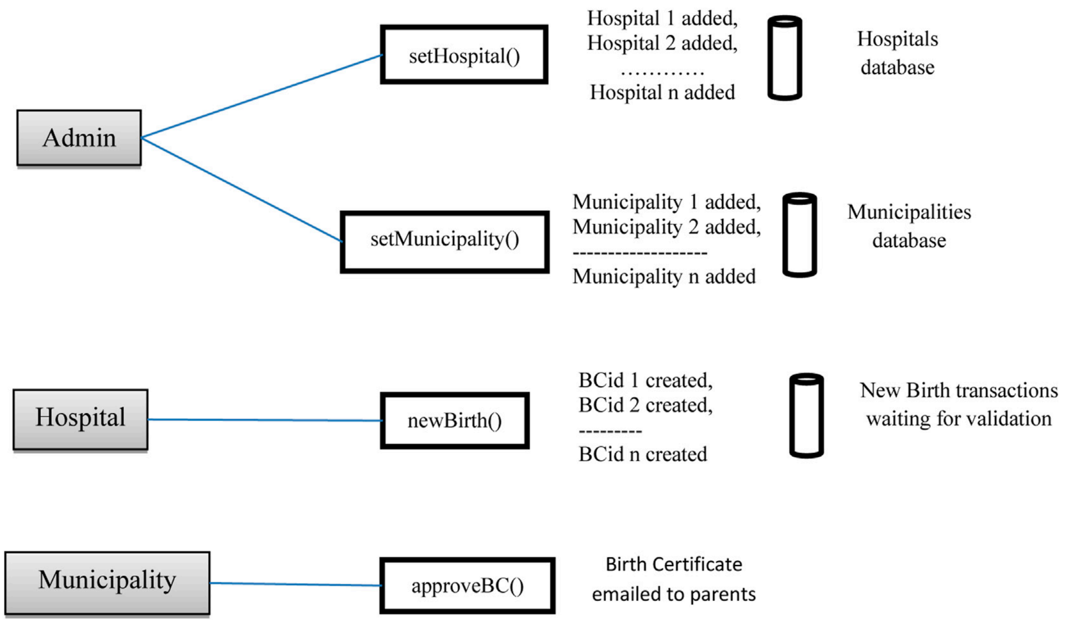

FIGURE 1
Functionalities of various BirthChain stakeholders.

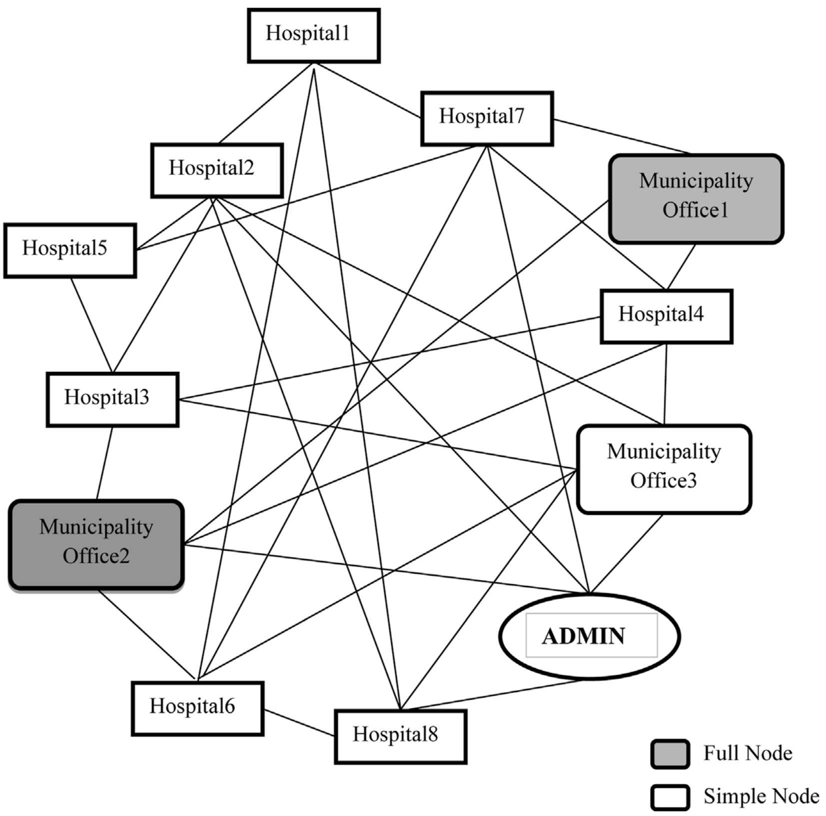

FIGURE 2
BirthChain architecture.

applications have revolutionized the financial and non-financial sectors and changed the way of working.

In the government sector, blockchain is being used for building trust, transparency, and robustness in the public sector. Researchers and organizations are working in the direction of blockchain-based e-governance, tamper-resistant certificates, identity management, and know-your-customer (KYC) verification. Blockchain is seen as a secure way of digitizing the documentation process. Blockchain-based self-sovereign identity (SSI) systems (Ahmed et al., 2022) are used for identity management, which provides control to the user to manage their access to their own identity without any centralized control. Similarly, Estonia has built a decentralized digital identity ecosystem (Espinosa and Pino, 2025) and is working on e-government as a development strategy for its country.

Apart from blockchain-based identity management, blockchain-based digital systems are being incorporated in countries like India (Thakur et al., 2020), Rwanda, South Africa, and the Philippines for birth certificate systems (Bennett et al., 2022), notarization (Deepika et al., 2025), civil registration systems (Djuraev et al., 2025), and land records (Maheshwari and Kumar, 2025). In Gasabo, Rwanda (Hughes, 2022), land notaries and registrars use a blockchain-based web application that is integrated with the existing Rwandan system and the Rwanda National Identity Agency to securely process the land records on blockchain. In the Philippines (Verde and Ganiron, 2024), proposals to incorporate smart contracts and blockchain have been proposed to address the problem of poor payments in the government construction industry. The Philippines is also incorporating artificial intelligence and blockchain as a part of its digital governance plan (Andaya et al., 2025) to strengthen its public services to citizens.

Researchers suggest that blockchain technology can transform public administration via its transparency, immutability, and security (Kothawade and Zellar, 2025). Various countries have experimented with blockchain technology to digitize their processes and found that the extended support provided by the tamperproof technology was sustainable for prolonged use. Blockchain is considered a transformative tool for secure government documentation systems. This study builds the foundation for proposing a robust blockchain-based birth certificate generation mechanism to digitize the existing paper-based birth certificate generation process.

4 Proposed BirthChain

Currently, blockchain is being used in a variety of government application areas. Success in these applications has motivated us to use blockchain to resolve the problem of the birth certificate registration and distribution process. The existing process is time-consuming and involves one of the parents visiting the municipality office once or twice. The process results in long delays. The proposed blockchain system for birth certificate registration and generation can ease the process and remove unnecessary delays. BirthChain is a permissioned blockchain-based digital platform for the registration and generation of birth certificates. It has been implemented using the Remix IDE (Latif et al., 2020) of Ethereum. Remix IDE provides an open-source platform for blockchain programming using Solidity or the Vyper programming language. It provides a variety of test networks to program and implement blockchain platforms using faucet Ethers. Whenever anyone does any transactions on the blockchain platform, he/she must pay the transaction fee in the form of Ether/Wei. Faucet Ethers are used to pay for the transactions under any of the test networks. These faucet Ethers can be earned using the faucet websites and can be used to do all the transactions in the test networks created.

Various stakeholders involved in BirthChain include the admin, municipality officials, and hospital administrations. All the stakeholders of BirthChain can access different functionalities and perform their respective roles. The functionalities of the BirthChain stakeholders are shown in Figure 1. The admin is given the sole permission to add hospital and municipality details to the blockchain network through the setHospital() and setMunicipality() functions, respectively. No other entity in the system has these permissions, ensuring high privacy of data and control of the admin over the network. Hospitals can only add the details of the new births happening in their hospital through the newBirth() function. The municipality, on the other hand, is allowed to validate the newborn details using the approveBC() function to generate birth certificates. At any point in time, anyone can view the details of hospitals or the municipalities with the help of their respective id.

The architecture of our proposed BirthChain system is as shown in Figure 2. All the participants of the network, including the admin, hospitals, and municipal offices, work in a distributed manner. The admin adds the hospitals and municipal committees to the blockchain network, and so it acts as a full node in the network. Apart from the admin, some of the municipalities are also selected as full nodes by the admin to keep multiple copies of the blockchain within the network and work in a distributed scenario. All the full nodes of the network store all the transaction history with them and are colored in gray in Figure 2. The nodes that can create new blocks, called miner nodes, are selected from among the set of full nodes on a rotation basis periodically. The miner node creates the block of transactions happening in the network and adds the block to the existing blockchain. Periodic rotation ensures fair data maintenance within the network.

4.1 BirthChain blockchain system workflow

The BirthChain system uses a smart contract to automate generating birth certificates and sending them to parents. The smart contract is deployed by the admin using its own Ethereum address as mentioned in Line 1 of Algorithm 1. The complete workflow of the BirthChain blockchain system is outlined in Algorithm 1. On contract deployment, the genesis block, that is, Block 0 of the BirthChain blockchain system, is created. Block 0 acts as the starting point of the blockchain system. It stores the timestamp of the creation of the block, the difficulty level of the block, its transaction cost, and nonce. At this point, the admin is the only participant in the blockchain network, and no transactions have happened yet. The admin assigns itself as the

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miner for the next block, that is, Block 1, as seen in Line 2 of Algorithm 1.

```
1: Admin deploys smart contract. This creates a genesis
   block (Block 0).
2: Admin assigns itself as a miner.//Admin is a full
   node too.
3: Set transaction_number = 0
4: Set timer = 0
5: If (transaction_number <10 || timer <15 min)
6: {
7: If (Admin)
   a: If(Node to be added==Hospital)
i: Admin provides the hospital’s name, location,
   phone number, and Ethereum address to setHospital()
ii: setHospital()//Adds hospital to the blockchain
    network
   b: ElseIf(Node to be added==Municipality)
i: Admin provides municipality’s location, pin code,
   phone number, and Ethereum address to setMunicipality()
ii: Admin enters 1 to select the municipality as a full
    node and 0 to make it a simple node
iii: setMunicipality()//Adds Municipality to the blockchain
     network.
8: ElseIf(Hospital)
a: Hospital provides newborn details: name, father’s
   name, mother’s name, date of birth, location,
   parents’ email addresses, municipality’s Ethereum
   address to newBirth()
b: newBirth()//Adds newborn details to the blockchain
   and sends a validation request to the concerned
   municipality
9: ElseIf(Municipality)
     a: Adds BCid to approveBC()
     b: approveBC()//validate newborn details, automatically
        create the birth certificate, and email it to parents
10: Hashed transaction is added to the transaction pool.
11: transaction_number++
12: Go to Line 5
13: }
14: Miner creates a new block.
     a: Miner evaluates nonce.
     b: Miner evaluates root hash.
     c: Miner appends the timestamp of block creation.
     d: Miner appends the transactions from the
        transaction pool.
15: Full nodes add the new block to the existing
    blockchain.
16: The new block is shared among all nodes of the
    blockchain network.
17: If (request for a new transaction)
    a: A new miner is assigned from among the set of full
       nodes on a rotation basis.
    b: Go to Line 3
```

Algorithm 1. BirthChain Blockchain System.

A block in the BirthChain contains at most 10 transactions and is created within every 15 min; that is, a full node can be a miner only for 15 min at a time. Once a miner is assigned, “transaction_number” is assigned a value of 0 (Line 3), which means that there are no transactions in the new block yet. Whenever any node in the blockchain network adds a transaction to the transaction pool, the “transaction_number” is incremented. “timer” is also assigned the value 0 (Line 4), which signifies the duration of a full node to be a miner. The timer also starts after the assignment of the miner. The transactions in the BirthChain include:

- Addition of hospital or municipality to the blockchain system by the admin.
- Addition of newborn details by the hospital.
- Validation of the newborn by the municipality.

There can be a transaction request from any of the three participants in the BirthChain system, that is, admin, hospital, and municipality. The admin can add hospitals and municipalities to the blockchain network through setHospital() and setMunicipality() functions, respectively, as shown in Lines 7a and 7b. Four fields are required to add a hospital to the blockchain network: name, location, contact number, and Ethereum address of the hospital. The admin is required to provide all the details of the hospital. The process of adding hospitals to the blockchain network is outlined in setHospital() as given in Algorithm 2.

The admin can also add the municipalities to the blockchain network, as shown in Line 7b through the setMunicipality() function, which requires the location, contact number, pin code, and Ethereum address of the municipality. The admin also has the choice of selecting the corresponding municipality as a full node or a simple node. For the full node, the admin enters 1 else 0 in the “full_node” field, as shown in Line 7b. ii. Once the details are provided, the setMunicipality() function is invoked. The process involved in setMunicipality() is outlined in Algorithm 3.

Hospitals are allowed to register the newborn on the blockchain platform. The process of birth certificate registration starts when a child is born in the hospital, and the details of the newborn are added by the hospital authorities, as shown in Line 8 of Algorithm 1. To register a new birth, the hospital authorities must provide the following details of the child: child’s name, father’s name, mother’s name, the date of birth of the child, time of birth of the child, the location of the hospital, the parents’ email addresses, and the corresponding municipality’s Ethereum address. Earlier, these details were kept by hospital authorities for record purposes. Through BirthChain, these details will be maintained by hospitals as well as shared directly with the municipality offices concerned. Once the details of the newborn are added by the hospital to the newBirth() function, a request is sent to the concerned municipality. The process is outlined in Algorithm 4.

The municipal authorities receive a notification whenever a newborn is registered by the hospital. They validate the newborn details added by the hospitals. They provide the BC_id to the approveBC() function, as outlined in Line 9a of Algorithm 1. The process of approveBC() is outlined in Algorithm 5.

Every time an admin, hospital, or municipality performs their task, the hashed transaction is added to the transaction pool, and the count of transactions is incremented, as shown in Lines 10 and 11, respectively. The values of “transaction_number” and “timer” are then checked in Line 5 to check whether a new block can be mined or not. If the “transaction_number” is 10 or the “timer” is 15 min,

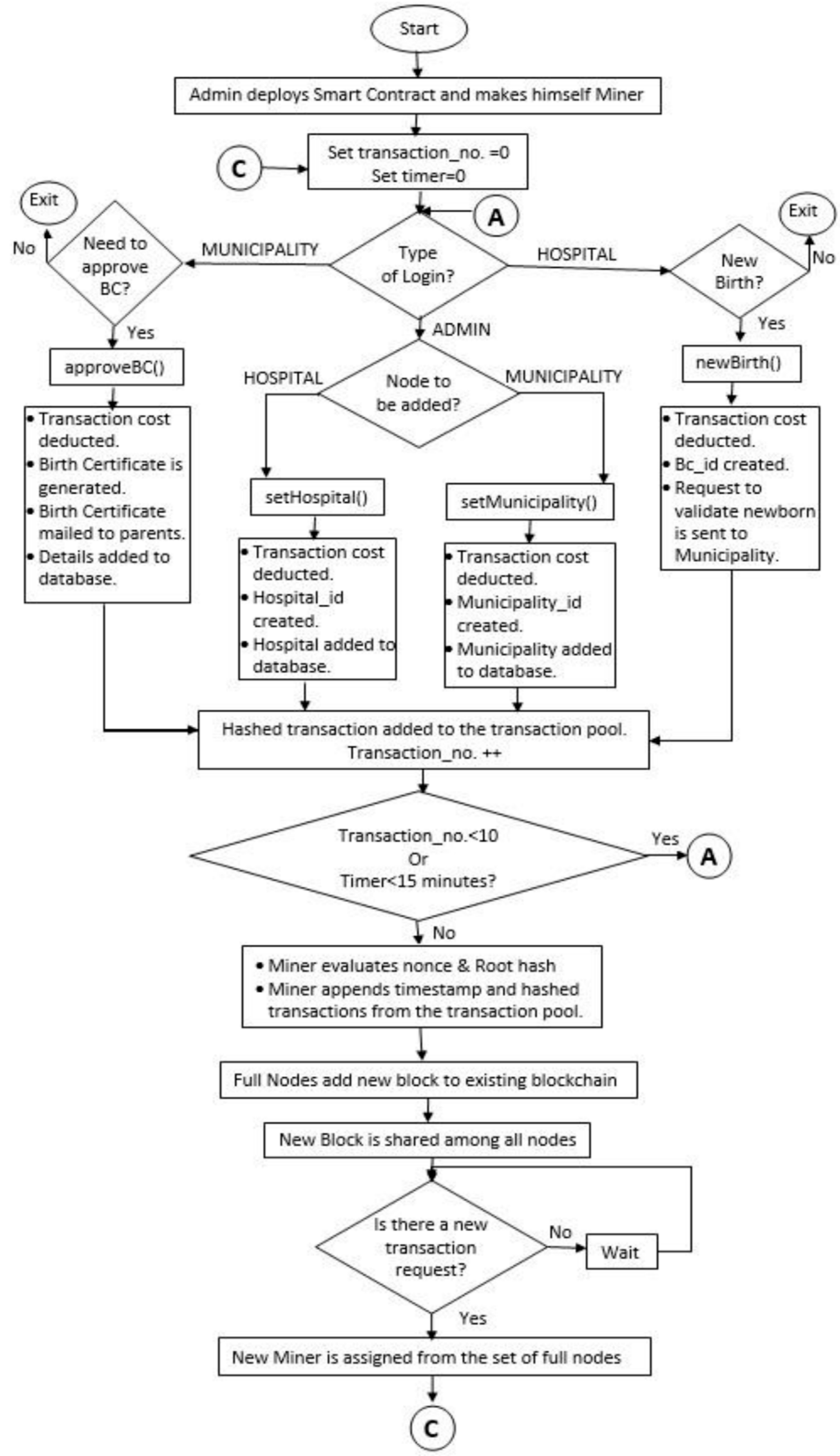

FIGURE 3
BirthChain blockchain system workflow.

the miner creates the new block; else, it accepts more transactions from any of the miner nodes in the blockchain network. To create a block (Line 14), the miner evaluates the nonce and root hash values. The miner also appends the transaction pool and the timestamp to the block. Then, the full nodes save the block in their databases to complete their copy of the blockchain, and the new block is shared among all the participants of the blockchain network.

Whenever there is a request for a new transaction by any of the participants on the network, a miner is assigned from the set of full nodes on a rotation basis, and the whole process continues. The

FIGURE 4
Deployed BirthChain smart contract.

complete workflow of the BirthChain blockchain system is also shown graphically in Figure 3.

The setHospital() function is used to add a hospital to the blockchain network. A transaction cost is deducted, and a hospital ID is assigned to the hospital, as seen in Algorithm 2. Furthermore, the hospital details are added to the database of hospitals. This successfully adds the hospital to the blockchain network so that it can add the details of all the new births happening at any time.

```
1: Transaction cost is deducted from the admin's Ethereum account.
2: Hospital_id is created.
3: Hospital details are added to the hospital's database.
```

Algorithm 2. setHospital ().

The setMunicipality() function is to add a new municipality to the existing blockchain network. A transaction cost is deducted, a municipality id is created, and the details are added to the database of municipalities as seen in Algorithm 3. This adds the municipality to the blockchain network so that it can validate the request for the generation of the birth certificate of the newly born, as requested by the hospital concerned.

```
1: Transaction cost is deducted from the admin's Ethereum account.
2: Municipality_id is created.
3: Municipality details are added to the Municipality database.
```

Algorithm 3. setMunicipality().

For registering the newborn through the BirthChain blockchain system, a transaction cost is deducted from the hospital's Ethereum account, and a BC_id is created as outlined in Algorithm 4 for the newBirth() function. A request is also sent to the concerned municipality to validate the newborn details, as seen in Line 3.

```
1: Transaction cost is deducted from the hospital's Ethereum account.
2: BC_id is created.
3: A request to validate the newborn details is sent to the concerned municipality.
```

Algorithm 4. newBirth().

When the municipality wants to approve the newborn details to generate the birth certificate of the child, a transaction cost is deducted from the municipality's Ethereum account, as outlined in Line 1 of Algorithm 5. The birth certificate is automatically generated and emailed to the parents. These details are added to the birth certificate database.

```
1: Transaction cost is deducted from the municipality's Ethereum account.
2: Birth certificate is generated.
3: Birth certificate is emailed to the parents.
4: Birth certificate details are added to the birth certificate database.
```

Algorithm 5. approveBC().

4.2 BirthChain: implementation

The BirthChain system has been programmed using the Solidity programming language and executed on the Remix IDE. The smart contract of BirthChain is deployed at the address 0xd9145CCE52D386f254917e481eB44e9943F39138. Figure 4

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TABLE 1 Ethereum addresses information.

Test account name/Contract name	Ethereum address
BirthChain blockchain system	0xd9145CCE52D386f254917e481eB44e9943F39138
Admin	0x5B38Da6a701c568545dCfcB03FcB875f56beddC4
Janta hospital	0xAb8483F64d9C6d1EcF9b849Ae677dD3315835cb2
Municipality 1	0x4B20993Bc481177ec7E8f571ceCaE8A9e22C02db

shows the deployed BirthChain smart contract with its eight functions. The contract is executed in the Remix virtual machine (VM) environment, which provides several test accounts with faucet Ethers to experiment with smart contract deployments and execution. Various test accounts are used in BirthChain. Some of the important accounts and their corresponding Ethereum addresses are listed in Table 1. The admin deploys the smart contract and is given the rights/permission to add the hospital and municipality accounts to the blockchain network. No one else is allowed to add these units to the blockchain network. This ensures privacy and control over the maintenance of the network.

The admin adds municipalities and hospitals to the blockchain network through setMunicipality() and setHospital() functions, respectively, as shown in Figures 5, 6. These municipalities and hospitals can be added whenever required to scale up the blockchain network. The admin provides all the required fields to the functions and pays the required transaction fee. This creates a municipal_id/hospital_id for the municipality/hospital added and adds the details to the respective databases. Once a hospital is added to the network, it can add the details of all the new births happening in real-time. Similarly, after a municipality is added, it can approve the new birth happening in its area.

Hospitals of the blockchain network can add the newborn details through the newBirth() function, as shown in Figure 7. Much information, including the child's name, parents' names, date of birth, and time of birth, is provided by the hospital. In addition, a parent's email id must be provided, which will be used by the blockchain system to share the birth certificate automatically once the registration is approved by the municipality. Hospitals also provide the concerned municipality's Ethereum address so that the blockchain system can send a notification to them for the verification of the newborn's details.

Once a hospital successfully adds the newborn details, the concerned municipality receives a notification to approve the newborn details for creating the birth certificate and sharing it with the parents. The municipality gives the Birth_id of the newborn to approveBC () to validate it as shown in Figure 8. This function automatically generates the birth certificate of the child with the details provided by the hospital while registering the newborn on the blockchain system. In addition, the birth certificate is then automatically emailed to the parents at the email ID provided by the hospital.

The functions newBirth() and approveBC() are used by hospitals and municipalities, respectively, to register the newborn and send the birth certificate to the parents. These functions are accessed only by the already-added hospitals and municipalities. At any point in time, the details of these birth certificates, hospitals, and municipalities can be checked using their respective id through the BCDetails(), birthCertificate(), hospital(), and municipality() functions, as shown in Figure 9. These read-only functions can be accessed by any of the participants on the blockchain network to examine the details. These functions are meant to check or simply learn the details anytime.

All these functions make the BirthChain smart contract a complete digital and secure solution to the existing process of manually completing the application for birth certificate generation at the municipality office. All the information shared on the blockchain platform is encrypted and stored securely on the blockchain network. The historical data can be viewed at any time, and because only the admin can add the trusted hospital and municipality to the blockchain network, the data are authentic and always secure.

4.3 BirthChain: discussion, results, and challenges

BirthChain is a proposed permissioned blockchain network for digitizing the existing birth certificate registration and generation process. The designated stakeholders, including hospitals and municipality employees, are added to the blockchain network by the admin only. It involves two major steps: newborn registration, which is done by hospitals via the newBirth() function, and newborn validation, which is done by the municipality committee via the approveBC() function. This simple process automatically generates the birth certificate of the child and sends it to the parents. Automatic programming through smart contracts makes the process much easier. Apart from birth certificate registration and generation, the BirthChain system can also be used to show the details of the hospitals and municipal committees.

The proposed BirthChain system does not require any parental visit for either certificate registration or receipt. It also improves the existing birth certification registration and generation process by making it completely digital. There is very little need for documentation during the process compared to the current certificate generation system. Our proposed system is a blockchain-based digitized platform. All the personal details stored on the blockchain network are encrypted and hence comply with GDPR and India's Personal Data Protection Bill. Hence, the data remain safe and secure on multiple servers within the blockchain network. The digital data can be easily used for analysis or making predictions.

The proposed blockchain platform is implemented using Ethereum's Remix IDE (https://remix.ethereum.org), a browser-based Solidity IDE with a built-in compiler, debugger, and

FIGURE 5
setHospital() execution.

FIGURE 6
setMunicipality() execution.

deployer. BirthChain has been deployed and tested using the Remix VM environment without using any real Ethers or money. It can migrate from Remix IDE to real-world deployment on any Ethereum Virtual Machine (EVM)-compatible blockchain like Ethereum (Metcalfe, 2020), Polygon PoS (Rana et al., 2023), BNB Smart Chain (Fior, 2024), Avalanche C-Chain (Kaur et al., 2025),

FIGURE 7
newBirth() execution.

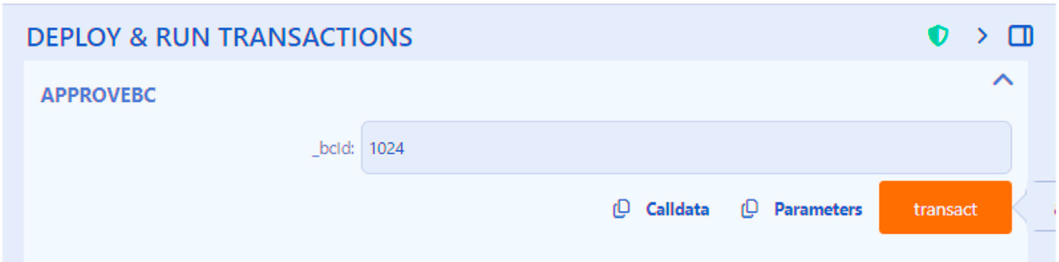

FIGURE 8
approveBC() execution.

and Fantom Opera (Tien et al., 2024). The performance analysis of the blockchain platform can be measured in the following parameters:

- Gas consumption: Every transaction on the blockchain consumes "gas" to execute. This metric measures the computational cost of deploying and executing functions on the blockchain network. Gas consumption is highest for contract deployment (done once), high for creating records, and very low for retrieving data. Any increase in the network load of the blockchain network increases the gas fee. A higher load means high gas consumption
- Execution latency: It is the time taken to execute contract functions and is generally measured in milliseconds (ms). Execution is normally fast but can slow down if there is a high load on the blockchain network.
- Storage utilization: Amount of blockchain storage consumed by structured data entries. Storage costs grow linearly with the number of records. Each structured entry (e.g., document hash + metadata) requires approximately 120–150 bytes, which is a low on-chain footprint, reducing long-term operational costs.
- Scalability behavior: Effect of increasing numbers of platform operations on cost and latency. Blockchain platforms are scalable and stable, making them suitable for mid-scale

FIGURE 9
BCDetails(), birthCertificate(), hospital(), and municipality() execution.

government document workflows where transactions occur at moderate frequency (less than 100 transactions per second).

To accurately estimate the financial implications of deploying and interacting with smart contracts, it is essential to examine several cost-influencing variables. In blockchain-based systems, every operation consumes computational resources, which are quantified as "gas" and paid for using the native token of the network. Therefore, costs are directly affected by the complexity of the smart contract code, the number and type of transactions performed, and the storage requirements on the distributed ledger. Additionally, real-time network conditions, particularly transaction demand and congestion, can lead to dynamic fluctuations in gas prices. The market volatility of cryptocurrencies further introduces uncertainty, as token-to-fiat conversion rates may shift significantly within short time spans.

The cost of a transaction in blockchain systems is determined by three key factors: gas usage (transaction complexity), gas price (network demand), and native token price (market volatility) and is calculated as:

Total transaction cost = gas used × gas price × token market price.

For the evaluation shown in Table 2, typical gas usage is assumed for three common operations: approximately 200,000 gas units for contract deployment, 50,000 gas units for creating a record, and approximately 200 gas units for a read transaction. Network gas prices are assumed to be 5 Gwei for Ethereum, 50.7 Gwei on Polygon PoS, 0.05 Gwei on BNB Smart Chain, and 0.001 Gwei for AVAX and FTM. The estimated exchange rates sourced from CoinGecko (CoinGecko, 2025) on 4 December 2025 include:

- ₹288,923 per ETH
- ₹82,216 per BNB

TABLE 2 Cost evaluation on a live blockchain network.

BlockChain/Token	Operation	Gas used	Approx. cost (native token)	Approx. cost (INR)
Ethereum (ETH)	Contract deploy	200,000	~0.004 ETH	~ ₹ 1,155
Ethereum (ETH)	Write (50,000 gas)	50,000	~0.001 ETH	~ ₹ 289
Ethereum (ETH)	Read (200 gas)	200	~0.000004 ETH	~ ₹ 1.2
BNB Smart Chain (BNB)	Contract deploy	200,000	~0.00001 BNB	~ ₹ 0.82
BNB Smart Chain (BNB)	Write	50,000	~0.0000025 BNB	~ ₹ 0.20
BNB Smart Chain (BNB)	Read (200 gas)	200	~0.00000001 BNB	~ Negligible (<₹ 0.01)
Polygon PoS (MATIC)	Contract deploy	200,000	~0.01 MATIC	≈ ₹ 0.30
Polygon PoS (MATIC)	Write	50,000	~0.0025 MATIC	≈ ₹ 0.07
Polygon PoS (MATIC)	Read (200 gas)	200	~0.000004 MATIC	Negligible
Avalanche C-chain (AVAX)	Contract deploy	200,000	~0.02 AVAX	~ ₹ 26.5
Avalanche C-chain (AVAX)	Write	50,000	~0.005 AVAX	~ ₹ 6.6
Avalanche C-chain (AVAX)	Read (200 gas)	200	~0.00002 AVAX	~ ₹ 0.03
Fantom Opera (FTM)	Contract deploy	200,000	~0.02 FTM	~ ₹ 0.19
Fantom Opera (FTM)	Write	50,000	~0.005 FTM	~ ₹ 0.05
Fantom Opera (FTM)	Read (200 gas)	200	~0.00002 FTM	Negligible

TABLE 3 Suitability comparison for birth certificate record system.

Blockchain network	Performance (throughput and latency)	Governance and trust	Cost predictability	Remarks
Ethereum Mainnet	Moderate, subject to congestion	Highly decentralized, strongest security	Low predictability (volatile fees)	Not suitable as a primary execution layer
Private Ethereum (enterprise)	Tunable, suitable for controlled environments	Trusted consortium governance	Predictable	Mature tools and strong compliance alignment
BNB Smart Chain (public)	High throughput	Highly centralized validator governance	Good but exposed to market variation	Governance centralization concerns
Avalanche Subnets (permissioned)	Very high, customizable	Consortium-controlled validators with strong finality	Highly predictable	Excellent for secure, regulated deployments
Polygon Supernets (permissioned)	Very high, low latency	Controlled validator set with strong tooling and L2 interoperability	Highly predictable	Excellent balance of cost/ performance for e-gov
Fantom private deployment	High throughput and fast finality	Consortium-based trust	Predictable	Good option, but less enterprise adoption

- ₹1,326.45 per AVAX
- ₹17.17 per MATIC
- ₹9.69 per FTM

5 Conclusion and future work

Digital platforms like BirthChain meet the needs of the hour in today's scenario. These platforms are preferred over the existing processes, as all the work is done digitally with less documentation at all levels. The proposed BirthChain system is a blockchain-based digital platform that includes hospitals and municipal committees as the major stakeholders of the network. Any transaction done within the network can be tracked easily. Transactions are encrypted and stored chronologically in the network. Hence, the data are safe from cyber theft and other cybercrimes. The birth registrations are done digitally and directly by the hospital authorities, ensuring timely, legitimate data entry into the blockchain system and preventing any false or misleading information. The system involves simple functions for registration by hospitals and verification by the municipal committees. The platform is easy to use for anyone with basic computer knowledge.

For a government birth record and certification system, blockchain platforms must support rigid access control, regulatory compliance, and long-term data integrity, with transaction speed and predictability. The Ethereum Mainnet is constrained by high and volatile transaction fees that make it unsuitable as the primary execution network for large-scale public services. However, enterprise-grade private Ethereum networks can provide the same mature tooling with permissioned governance. On the other hand, BNB Smart Chain delivers higher throughput at low cost but with a relatively centralized governance, a trait that raises concerns for sovereign control and transparent auditability in public administration. In contrast, Avalanche Subnets and Polygon Supernets support dedicated permissioned EVM chains that enable government agencies to define validator membership, allow for compliance with jurisdictional regulations, and achieve fast confirmation times with predictable costs while still preserving interoperability with broader public ecosystems when that is needed. Fantom-based private deployments also offer robust performance and fast finality, but the ecosystem currently features fewer enterprise implementations than Ethereum-derived or Avalanche/Polygon frameworks. Therefore, within a government certification and records domain where institutional trustability, operational performance, and controlled governance are fundamental, Avalanche Subnets and Polygon Supernets present a strategically favorable balance between decentralization, cost efficiency, and regulatory oversight. Table 3 gives a comparison of the blockchain platforms.

The best technical fit for a live blockchain system for birth certificates would be a permissioned EVM chain on top of an Avalanche Subnet or Polygon Supernet because they offer strong support for regulated governance, scalability, and predictable operational costs while still allowing interoperability with broader blockchain ecosystems. In addition, in the future, BirthChain can be extended to record the date of death and generate death certificates as well. This will provide better insights into the data, including average age and life expectancy. Various other data analyses can be conducted based on the geography of the city, state, or country, year-wise.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material; further inquiries can be directed to the corresponding authors.

Author contributions

RS: Writing – review and editing, Conceptualization, Writing – original draft. SU: Writing – review and editing, Writing – original draft, Supervision, Visualization. SM: Writing – review and editing, Data curation, Methodology, Writing – original draft. SA: Validation, Formal analysis, Writing – original draft, Writing – review and editing. PD: Writing – original draft, Methodology, Writing – review and editing, Supervision.

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The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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