

Article

Blockchain Solutions for E-Tenders in Public Procurements

Veneta Aleksieva *  and Hristo Valchanov 

Faculty of Computer Sciences and Automation, Technical University of Varna, 9010 Varna, Bulgaria;
hristo@tu-varna.bg

* Correspondence: valeksieva@tu-varna.bg

Abstract

Public procurement tenders in Bulgaria are in the focus of public attention, despite the transparency of the process, which is conducted online through the Public Procurement Agency platform, participants require greater trust in the conduct of the procedures themselves, as they are not yet fully automated. Blockchain solutions are used in a wide range of businesses, as they offer transparency of transactions, trust between parties and data immutability and also seem suitable for conducting e-tenders for public procurement. This publication offers a solution based on a private blockchain HyperLedger Fabric, which in terms of structure and functionality builds on the existing solution. It ensures bidder identities are confidential from the unauthorized participants and transparency of the work of administrators in the platform and their actions when changing the status of a public procurement. The proposed blockchain based solution improves the evaluation process, reducing certain technical and human-error risks. The results show that it provides greater transparency and efficiency in the spending of public funds, achieving the set quantitative indicators with automated evaluation and qualitative factors defined in the smart contract.

Keywords: blockchain; HyperLedger Fabric; e-tender; e-auction

1. Introduction

Public procurement tenders in Bulgaria are a legally regulated, relatively transparent and partially automated processes. The frequent changes in governments, and hence the amendments to the Public Procurement Act [1] (29 times in the period from 2016 to 2026) and the Regulations for the Implementation of the Public Procurement Act [2] (amended nine times over the same period), make our society extremely sensitive to the spending of public finances. The concerns of the society are that there should be no corrupt practices, while those of the public procurement participants are about unusual settings of the tender procedures and the auction, the inclusion of discriminatory criteria that point to a specific candidate, or indirect and not so obvious links between the commission and a participant in the procedure. In Bulgaria, the Public Procurement Agency (PPA) maintains a Public Procurement Portal [3]. The emergence of online platforms [4,5] with detailed information on training, webinars, instructions for announcing public procurement, instructions and expert assistance for preparing tender documentation by participants makes the process transparent, but does not increase confidence in the conduct of the procedures themselves, as they are not yet fully automated.

The European Commission published two types of public procurement notices through the online public procurement portal (Tenders Electronic Daily—TED) [6–8], but they are only informational and for the submission of documents, and do not conduct the tenders



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themselves. An interesting platform for European countries is Tendify [9], through which one can find an open tender procedure suitable for a specific business.

Since 2020, an e-procurement platform [10] has been operating in Bulgaria, which is a single access point for all information on a specific tender procedure and ensures transparency and efficiency in the spending of public finances. It is fully compliant with TED and follows a similar structure and functionality, as it is financed and developed under a European project. The platform provides 16 modules and does not allow documents to be manipulated, as they are signed with a qualified electronic signature. In the platform, offers are stored encrypted with a unique key generated in the participant's browser, and the time stamp is provided by a service provider certified by the Communications Regulation Commission. However, the selection of the winner is not made in real time and the official announcement of the winner takes from several days to several weeks depending on the internal deadlines of the contracting authority. Every participant has the possibility to see in real time the best offered price. This is required by the Public Procurement Act [2], which requires that after the auction is closed, the contracting authority's commission must examine the offers, starting from the best price, checking whether it meets all other conditions of the order. The commission prepares an official protocol with the final ranking. This document is uploaded to the system and becomes accessible to all participants. The contracting authority issues an official "decision to determine the contractor". Only with this document the winner is officially selected. After the decision is published in the Public Procurement Register, a legal period begins, during which other participants can appeal the procedure to the Commission for Protection of Competition (CPC).

According to the Public Procurement Act [2], public procurement may also be conducted by e-auction, and in the platform [10], when filling in the data for the public procurement, it is indicated whether an electronic auction will be used. In this case, the contracting authority indicates that an electronic auction with real-time bidding will be used when selecting a contractor for the specific procurement and allows the creation of bid variants by the participants. In multi-stage procurements, the electronic auction is always visualized in the last stage, and if the procurement has separate items, an electronic auction can be held for each separate item.

An effective public procurement system improves public administration by addressing issues such as corruption and waste of public funds. Such systems should offer security, transparency, immutability, sustainability, but also be fast-tracked. They should offer a fair and transparent environment for bidding and monitoring. All these needs direct scientific thought and creativity towards the application of blockchain technologies in this area.

Currently, no country in the European Union (EU) has fully replaced its national public procurement system with a blockchain solution, but numerous pilot projects are underway, and from 2021 a pan-European EBSI infrastructure [11] is being built, consisting of peer-to-peer nodes in 27 EU countries, Norway and Liechtenstein, and in 2026 the best practices in this area are published [12]. One of the main scenarios is the use of blockchain to manage the European Single Procurement Document and e-Certis certificates. This will allow companies to prove their compliance (lack of liabilities, criminal record, etc.) via blockchain, without having to pull documents from dozens of institutions. The European Commission is funding a Blockchain Pre-Commercial Procurement (PCP) project worth €7 million [13]. It involves leading technology companies (such as IOTA and Chromaway), which have developed solutions for automation through smart contracts, data traceability and secure storage, allowing integration with IoT (automatic payment upon confirmed delivery of goods via blockchain). In [14] the application of blockchain technology in pilot solutions for public procurement in Estonia, Spain and Belgium are examined, focusing on its role in increasing transparency, security and efficiency. The regional government of

Aragon (Spain) is implementing a real project to record the stages of the tender process on blockchain to ensure transparency [15].

The idea of using blockchain to monitor public spending through public procurement is also relevant worldwide. In 2019, Seoul district of Yeongdeungpo-gu (South Korea) created a digital bidding platform that also uses a blockchain record to store individual evaluations of members of the evaluation committee for bids from suppliers for public procurement [16]. These evaluations are initially stored in an internal database that serves the digital bidding platform, and then transmitted and stored along with a time stamp on a private blockchain that is based on Hycon's patented technology. The Philippine government is using blockchain technology before a procurement is initiated to record the availability of regular and irregular supplies within the Office of Public Procurement's Warehousing and Inventory Management Systems [17]. Mexico, in order to combat corruption in public procurement, is jointly offering a Hyperledger Fabric-based blockchain solution with the state of Jalisco, integrated (in a test environment) with the state's central procurement platform, the SEPAP System. It aims to create traceable, immutable, transparent, and reliable processes such as storing a request for the supply of an item on the blockchain; routing the request to a procurement specialist; assigning a procurement specialist; and publishing a contract notice.

In ref. [18], a hybrid consortium blockchain integrated into the Kosovo e-procurement platform is proposed. Smart contracts automate budget commitment checks and bid validation, minimize manual errors and delays, and eliminate fraud and verification delays. The combination of public and private blockchains balances transparency with data confidentiality, allowing for real-time auditing and permissioned access to sensitive information.

The analysis of problems in the public procurement sector and possible solutions in [19] and the systematic review [20] of the global implementation of blockchain technologies in the public sector between 2019 and 2025 highlight that blockchain technology improves transparency and efficiency through use in property registries, digital identity and public procurement, despite challenges related to interoperability and regulatory uncertainty.

In ref. [21] an analysis of the public procurement sector in Ghana is presented, in ref. [22] in Bangladesh and in ref. [23] for developing countries in Africa without specification which ones. They analyze the problem of public procurement in developing countries and focus on blockchain-based solutions, since such would overcome the problem of corruption in this sector in developing countries. Several aspects of corruption are considered-bid evaluation is the most critical stage susceptible to corruption, followed by contract management and public procurement planning in the stages of public procurement. The goal is to minimize factors such as information asymmetry, moral hazard and adverse selection.

Following the global and European trends towards blockchain solutions in the field of public procurement, which ensure confidentiality of bid and participant data, transparency of the actions of participants in the process, irrevocability, provability and trust between participants, the transition to a blockchain-based solution using a private blockchain such as Hyperledger Fabric would transform the existing Bulgarian public procurement platform [10] from a "file submission system" into an "automated trust system", where manipulation of documents after submission becomes mathematically impossible. This would be practically possible if a change is made to the legal framework, whereby the blockchain ledger must be recognized as official evidence in court (similar to the paper protocol) and is fully compatible with the European public procurement directives. This document proposes the technical solution for conducting e-tenders for public procurement, based on a private blockchain, indicating its advantages over the classic solution.

2. Classic E-Auction for Public Procurement in Bulgaria

The Public Procurement Recipient (PPR) may use an e-auction when the technical specifications of the contract can be precisely defined. It is suitable for standardized goods (fuels, finished materials, office supplies), but it is risky for complex services. Preparing an e-auction is a complex process, as it requires a precise mathematical formula for evaluation and a proper technical specification, so that it does not turn out that in the end the “cheapest but unusable” goods were purchased. Therefore, the Public Procurement Act [2] describes activities that cannot be automatically evaluated by a mathematical formula, since their quality depends on subjective expert skills, and not only on quantitative indicators. The main prohibitions are related to the nature of the subject matter of the contract and the protection of competition—intellectual activities such as scientific research, creative projects, consulting expert services, design of construction sites, where there are no clearly defined technical specifications of the contract or where competition is restricted.

In Figure 1 is shown the legally defined process of conducting an e-auction through the platform [10].

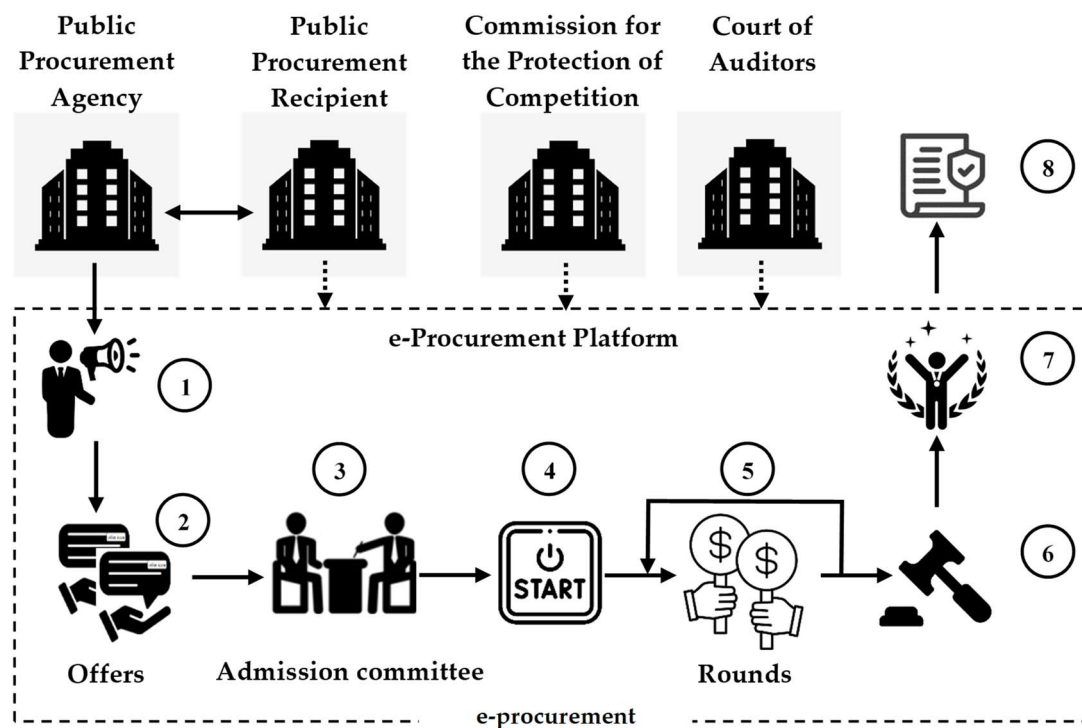


Figure 1. Classic e-auction for public procurement.

The necessary information for conducting an e-auction for public procurement is entered through the electronic form of the platform and includes:

- Description of the electronic auction and visibility for participants;
- Accuracy of the offers proposed by the participants by specifying the number of digits after the decimal point (maximum 6);
- Type of the bidding component—Bidding on a total price (there is an opportunity for participants to improve their offers, with each participant starting the bidding from the value of the offer provided by them); Bidding on a list of items (participants manually enter their initial offers and bid on prices of up to 10 items, the sum of which forms the final price at which the ranking in the electronic auction is carried out); Bidding on a parameter other than price (in this case, the bidding is carried out on a value other than price, e.g., “discount”);

- Currency;
- Type of electronic auction—standard bidding auction (higher value is better); reverse bidding auction (lower value is better);
- Minimum step by which participants can improve their offers;
- Minimum distance from the best offer—represents the minimum value by which the participant must improve the best offer at the time of bidding;
- Round duration—the time in which participants can submit their offers;
- Time between rounds—sets the time between two rounds;
- Method of completing the electronic auction—Two consecutive rounds without bids submitted by participants; Two consecutive rounds without changing the best offer;
- Start of the electronic auction—date and time on which the electronic auction will start after activation.

The conduction of the auctions is monitored by the National Audit Office and the Commission for the Protection of Competition. The steps of conducting an auction are as follows:

1. The Public Procurement Agency (PPA) announces an auction for a specific contracting authority.
2. Participants submit initial bids with certain parameters.
3. Admission of the participants by a committee. Those who are not removed by the contracting authority receive a notification in the system and by email.
4. An electronic auction is launched with a minimum of two participants whose technical and price bids are open and not removed.
5. The system displays information about the rounds held with the relevant bids submitted by the participants and the time of submission. After the completion of each round, the information is updated by calculating the ranking of the participants for the relevant round.
6. Submission of bids in the electronic auction ends automatically.
7. The closing action recalculates the ranking in the procurement based on the results of the electronic auction, the selected formula and award criteria, adding the final bid score from the electronic auction of each participant in the procurement. In the case of refusal or inability of the first ranked participant to conclude a contract, it is demarked as “admitted/selected” for the respective participant and the next participant in the list is marked. In case of two identical best results from the comprehensive evaluation, the system provides the contracting authority with the possibility to proceed to the selection of a contractor at random (lottery). The system automatically takes this possibility into account by making a random selection of a contractor, marks the respective economic entity as selected and informs the contracting authority about the selection made by displaying an information card.
8. After the selection of a contractor in a specific public procurement, the platform allows the creation of a contract for the respective procurement, in which subcontractors can also be specified. The system publishes an announcement that the respective public procurement has been awarded.

This method aims to ensure transparency, competition and efficiency in the spending of public funds, but still leaves some problems unresolved. Although electronic auctions aim to achieve the lowest price for the public resource, they pose serious risks for both contracting authorities and businesses. First of all, there is the risk of underestimating quality, since the e-auction is a mathematical model that prioritizes quantitative indicators (mostly prices) and ignores factors such as the participant’s experience, innovation and sustainability of the proposed solution. Second, there is the risk of “unrealistically low” prices, since in their quest to win, participants often enter into aggressive bidding and

fall below the cost price of the product or service. This leads to poor quality, because the contractor tries to “beat off” the loss through cheap materials or fewer personnel. If the participant in the tender realizes that he will work at a loss, he often refuses to sign a contract. This leads to an iterative procedure to find a participant from the ranked offers who is ready to conclude a contract. Large companies with huge capital can afford to undercut the market in order to eliminate competition. It is difficult for small companies to withstand a price war, which can reduce competition in a given sector in long term. Third, technical risks associated with a slow internet connection or a software problem at a critical moment can disqualify a participant, which reduces trust in the transparency of the procedure. Human errors are also a factor that should not be underestimated, as when working under pressure, a participant can enter incorrect figures and this can cost his company elimination from the tender due to an uncompetitive bid. Last but not least, there is a risk of oligopolistic agreements in specific niches with a small number of participants. The automated process cannot prevent participants from pre-agreement on how far to lower the price or who will win this particular bid, which makes the tender meaningless for the state. In this context, the question of how blockchain technology can improve the process of conducting public procurement naturally arises. By its very nature, blockchain ensures trust between participants, security of transactions, irrevocability and provability of actions, impossibility of tampering with already recorded data, and clear registration of the moment of each event in the blockchain network.

However, the centralized e-procurement platform [10] does not currently use blockchain technology for several reasons:

- By design and by law, the e-procurement platform is a centralized system managed by the Public Procurement Agency, while blockchain solutions are inherently decentralized (distributed among many participants). Thus, the use of blockchain at first glance contradicts the model in which a government body bears full responsibility for the storage and legitimacy of data. However, such an argument would be correct if a public blockchain is used, while the use of a private blockchain such as HyperLedger Fabric “closes” the responsibility for the storage and legitimacy of data to trusted devices that can only be hosted by the government body.
- The effort to maintain confidentiality of data at the initial stages of the public procurement (bids until their opening) through double encryption with unique keys generated in the user’s browser provides the necessary protection without the need of a blockchain. This is also mistakenly interpreted as an advantage over a blockchain-based solution, in which data is also stored encrypted and is accessible only to authorized peers, which provides the same degree of confidentiality.
- The system guarantees authorship and time of submission through qualified electronic signature and a qualified electronic time stamp, while in a blockchain-based solution the automatic time stamp and irrevocability of actions of the network participant can provide proof of non-discrimination and impossibility of manipulation of documents.
- Since the platform [10] is built on European projects with strictly defined interoperability requirements (e.g., with the European TED platform), including a blockchain would make the system unnecessarily expensive and complicated, since even using a private blockchain requires trained specialized personnel, which would make the system more expensive.

However, the current solution [10] does not provide transparency in the work of the orders’ administrators on the platform and the actions of the committees (change in status, evaluation, and extension of deadlines) and is often a reason for appealing the procedure in auctions, while the blockchain is inherently immutable.

It should be noted that the existing classical system also has a shortcoming—the inability to check for a conflict of interest between the participants and the beneficiary. Changing the back-end to include blockchain cannot eliminate this shortcoming, because such data is not currently available in the system. This requires checks in various registers with sensitive information for companies about their employees.

3. Blockchain-Based E-Auction Solution for Public Procurement

Implementing a private blockchain like Hyperledger Fabric in [10] requires a fundamental change in the architecture of the system. Hyperledger Fabric is suitable precisely because it allows for access control and confidentiality through “channels”.

In Figure 2 is shown a blockchain-based e-auction model for public procurement.

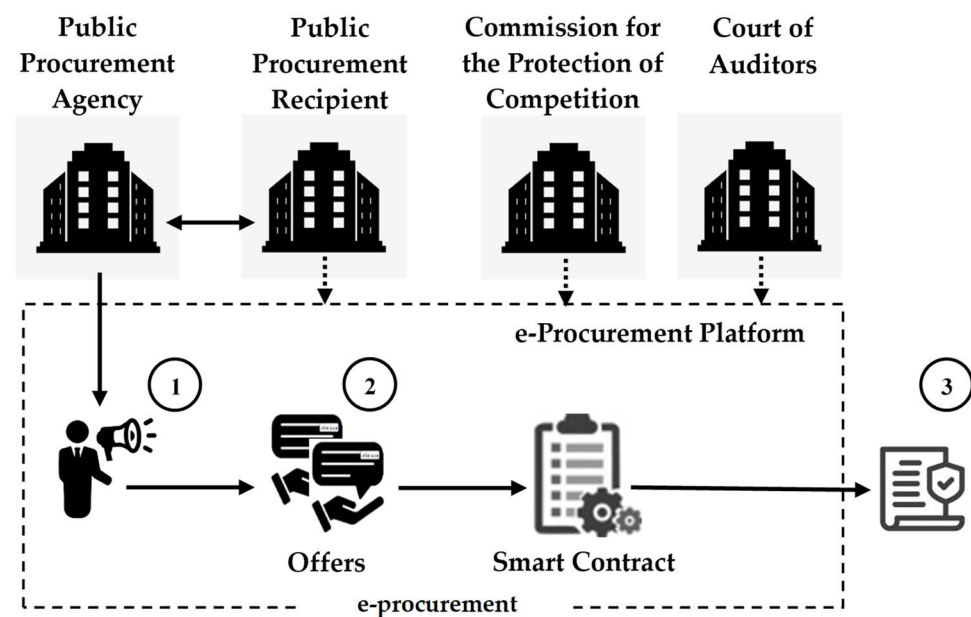


Figure 2. Blockchain-based e-auction model for public procurement.

The decentralized infrastructure is built with “peer” nodes, which are the Public Procurement Agency, the Court of Auditors, the Commission for the Protection of Competition and the Public Procurement Recipient. Thus, the data is not only on one server. A consensus mechanism between the nodes arranges transactions in blocks and ensures that no one can change the chronology of the offers, and the logic of the public procurement is in the program code. Isolated channels are created for each public procurement, where only the above participants have access to the content of the offers, while the metadata (when and who submitted the offers) remain publicly visible and unchangeable in the ledger for peers. The announcement of the tender (1) is again carried out by the Public Procurement Agency. The smart contract automatically “unlocks” the submitted offers (2) exactly at the opening time, without human intervention. Based on defined rules for each order, the smart contract checks whether a participant meets the minimum requirements, eliminating the need for an admission committee. The rounds and the ranking of the winning bidder are carried out automatically, thus eliminating the possibility of incorrect human intervention in the auction. As a result, a contract for the execution of the order is generated (3). It should be noted that in the proposed solution, as in the classical solution [10], the participants in an e-tender are not visible to everyone throughout the entire process of the procedure (regardless of the fact that they are recorded in the ledger). Only participants (authorized peers) admitted to the bidding stage see the movement and prices in real time, while

outsiders gain access only after the final closing. The system publishes the final values in the public or workspace of the e-auction to be visible to the public.

The Qualified Electronic Signature (QES) identification is integrated with blockchain keys by the HyperLedger Fabric Membership Service Provider. The public key from the peer's certificate is used to verify that the signature attached to the transaction is valid.

The implementation of the proposed blockchain model is on the HyperLedger Fabric (HF) platform. It is a private blockchain, convenient for creating business applications. HF is characterized by a modular organization; fast block transfer and fail-safe consensus mechanism. Each public procurement is represented through a separate channel storing information about the stages of the tender. The business logic is implemented through a smart contract for each individual procurement. The code is written in the Go language and includes parameters for assessing the eligibility of participants, according to the specific offer.

Algorithm 1 presents a pseudocode of the process of selecting a winner among the participants in the tender procedure. In the pseudocode, a mathematical formula for complex evaluation of the offers of individual participants is used to rank them. The formula includes the technical quality indicators specific to the respective subject of the tender (Tech_Points[Participant]) and the current offer price (Curr_Offer[Participant].Price).

Algorithm 1. Public Procurement Procedure Workflow

```

1. Input: Participants_List, Award_Criteria, Auction_Params
2. Output: Final_Ranking
   // FILTERING CANDIDATES APPROVED FOR TECHNICAL ASSESSMENT
3. Approved_Participants ← Admitted(Participants_List)
   // SET STARTING VALUES FROM INITIAL BIDS
4. For each Participant in Approved_Participants do
5.   Curr_Offer[Participant] ← Participant.Inital_Offer
6.   If Award_Criteria = "Optimal_Ratio" then
7.     Tech_Points[Participant] ← Participant.Tech_Assessment
8.   End If
9. End For
10. Curr_Round ← 1
11. Active_Auction ← True
12. Rounds_No_Change ← 0
   // MAIN BIDDING LOOP
13. While Active_Auction = True do
14.   Bids_Submitted_In_Round ← 0
15.   Best_Offer_Before_Round ← Get_Best_Offer(Curr_Offer)
16.   For each Participant in Approved_Participants do
       // CHECKING FOR PARTICIPANT ACTIVITY IN THIS ROUND
17.     If Participant.Submit_New_Offer(Curr_Round) then
18.       New_Offer ← Participant.Enter_Offer(Curr_Round)
       // CHECK IF THE OFFER MEETS THE BIDDING STEP
19.       If Validate_Step(New_Offer, Curr_Offer[Participant],
Auction_Params.Step) then
20.         Curr_Offer[Participant] ← New_Offer
21.         Bids_Submitted_In_Round ← Bids_Submitted_In_Round + 1
22.       Else

```

Algorithm 1. *Cont.*

```

23.         Reject_Offer(Participant, "Invalid Step")
24.     End If
25.     Else
26.         // THE LAST VALID OFFER IS RETAINED
27.         Curr_Offer[Participant] ← Curr_Offer[Participant]
28.     End If
29. End For
30. // AUTOMATIC RECALCULATION AND TIME RANKING AFTER THE ROUND
31. For each Participant in Approved_Participants do
32.     If Award_Criteria = "Lowest_Price" then
33.         Final_Points[Participant] ← Curr_Offer[Participant].Price
34.     Else If Award_Criteria = "Optimal_Ratio" then
35.         // MATHEMATICAL FORMULA FOR COMPLEX ASSESSMENT
36.         Final_Points[Participant] ←
37.             Recalculate_Comprehensive_Assessment(Curr_Offer[Participant].Price,
38.             Tech_Points[Participant])
39.     End If
40. End For
41. Temporary_Ranking ← Sort_Participants(Approved_Participants, Final_Points,
42.                                         Award_Criteria)
43. Show_Results(Temporary_Ranking)
44. // CHECKING THE END OF AUCTION CONDITIONS
45. Best_Offer_After_Round ← Get_Best_Offer(Curr_Offer)
46. If Best_Offer_After_Round = Best_Offer_Before_Round then
47.     Rounds_No_Change ← Rounds_No_Change + 1
48. Else
49.     Rounds_No_Change ← 0
50. End If
51. If Curr_Round >= Auction_Params.Max_Number_Rounds then
52.     Active_Auction ← False
53. Else If Rounds_No_Change >=
54. Auction_Params.Max_Number_Rounds.No_Activity then
55.     Active_Auction ← False
56. Else If Curr_Time() >= Auction_Params.End_Time then
57.     Active_Auction ← False
58. Else
59.     Curr_Round ← Curr_Round + 1
60. End If
61. End While
62. // FINAL RANKING AND EXPORT
63. Final_Ranking ← Sort_Participants(Approved_Participants, Final_Points,
64.                                     Award_Criteria)
65. Export_To_Bid_Evaluation(Final_Ranking)
66. Return Final_Ranking

```

The complex evaluation formula is the arithmetic mean:

$$R_a = \frac{\sum_{i=1}^n b_i d_i}{\sum_{i=1}^n b_i} \quad (1)$$

Each of the indicators (d_i) has a certain weight (b_i), determined by the contracting authority. The normalized quantitative assessment of the i th indicator is:

$$0 \leq d_i \leq 1 \quad (2)$$

where n is the number of indicators, a b_i is the i th weight coefficient, and the sum of all weight coefficients is one.

$$\sum_{i=1}^n b_i = 1 \quad (3)$$

The weighting coefficients are set by the contracting authority when announcing the requirements for the tenders for the subject of the tender. The indicators (d_i) are divided into technical and price. The technical indicators describe how the order is required to be fulfilled. These are:

- Characteristics of the subject of the tender-quality of materials, functionality, esthetic and environmental indicators;
- Organization of implementation-detailed work plan, allocation of resources and risk management;
- Qualification of personnel education and experience of the contractors;
- After-sales service terms and conditions for warranty support, technical assistance and logistics;
- Project completion deadline.

Price indicators can be more than one:

- Suggested price;
- Life cycle costs;
- Unit prices for specific details.

Price evaluation formulas are always designed so that the lowest price receives the maximum number of points, and higher prices receive proportionally fewer points.

Figure 3 shows the implementation of the proposed model as an HF network. There are three permanent participants (organizations): Org1—Public Procurement Agency; Org2—Court of Auditors; Org3—Commission for the Protection of Competition. The solid arrows represent the organizations' access to data in the respective channels. The dashed arrows represent peers' read/write operations on the channels.

Peer0 writes the parameters of the public procurement (according to the requirements of Org4) to the channel. Peer1 and Peer2 have read only access to all channels, as they have controlling functions. For each public procurement, there are additional participants (e-procurement 1 is considered, and for the other procurements it is analogous): Org4—Public Procurement Recipient; Org5 ... OrgN—participants in the specific auction. The Public Procurement Recipient has read-only access to the channel, while the other peers (Peer5 ... PeerM) have read/write access, as they record the bids in the rounds.

Because the classic solution [10] does not provide transparency in the work of the order administrators on the platform and the actions of the committees, the proposed blockchain-based solution (like any blockchain-based solution) ensures the irrevocability of the actions of the administrators regarding the parameters of the order (timestamp for changed status or extension of the deadline for the tender); an exact time stamp when adding documents by the participants in the procedure and the impossibility of changing the terms of the tender (bidding step, minimum price, stop price).

The ranking of the candidates is recorded in the blockchain irrevocably as a rank list and this provides public proof in the event of the refusal of the winning participant who is exactly next winner in the tender.

The most significant advantage of the proposed blockchain-based solution is the impossibility of making changes to the offers after the deadline for their submission.

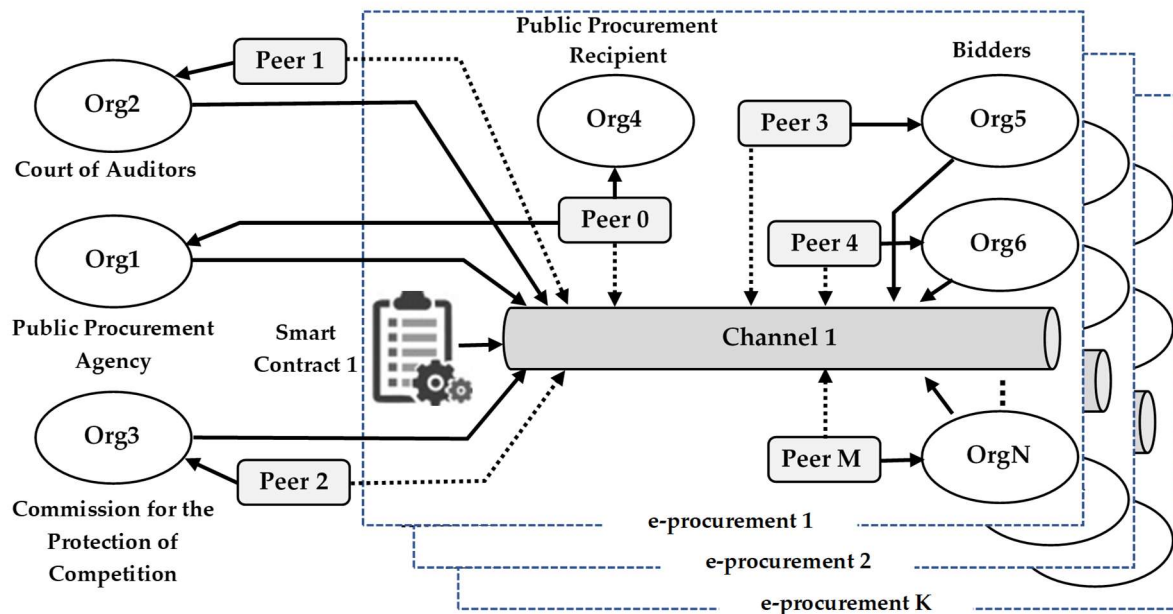


Figure 3. HyperLedger implementation of blockchain-based e-auction for public procurement.

4. Results

The functioning of HF is based on the use of the Docker virtualization platform. It provides encapsulated execution environments—containers. Each container runs independently of the others and has its own operating system. The code of each peer is executed in a separate container. A characteristic feature of Docker is that containers can be executed not only on one machine, but also on separate computing nodes. This allows for a distributed implementation of the proposed model. Figure 4 shows some of the launched containers. Communication is based on the TCP/IP protocol suite, with each container registered in HF with a separate port.

Interaction with the smart contract implemented in the Go language is performed by calling its methods, and various objects are used to store the information.

Testing the functionality of the proposed model was performed by sending requests to the corresponding smart contract and checking the correctness of the result of their execution. The requests contain an identifier of the requirements for the execution method and the necessary data. Testing is performed through a specially created *cli* container for executing command scripts.

Figure 5 shows the successful execution of the *CreateBidData()* method for storing information about a new bid for the corresponding round. Successful execution of the request is indicated by a success code of 200.

The extraction of information from the blockchain is shown in Figure 6. In this specific example, elements with information about the bids of a participant in the auction “Highway Construction Lot2” with the name “Compass Ltd.” are searched. The result obtained shows three actions of the participant, displaying the time and step of the bids. The code 200 is again an indication of the successful execution of the request.

CONTAINER ID	IMAGE	NAMES	COMMAND	CREATED	STATUS	PORTS
ba77e8520515	hyperledger/fabric-tools:latest	cli	"/bin/bash"	20 minutes ago	Up 19 minutes	
4d9208e8c227	hyperledger/fabric-peer:latest	peer0.org1.example.com	"peer node start"	20 minutes ago	Up 20 minutes	0.0.0.0:7051->
7051/tcp						
549355f3917b	hyperledger/fabric-couchdb	couchdb4	"tini -- /docker-ent..."	20 minutes ago	Up 20 minutes	4369/tcp, 5984
/tcp, 9100/tcp, 0.0.0.0:13984->13984/tcp						
51367e542d0a	hyperledger/fabric-orderer:latest	orderer4.example.com	"orderer"	20 minutes ago	Up 20 minutes	0.0.0.0:10050->
>7050/tcp						
fcaaf63b7c26	hyperledger/fabric-orderer:latest	orderer2.example.com	"orderer"	20 minutes ago	Up 20 minutes	0.0.0.0:8050->
7050/tcp						
6b6ac546a1aa	hyperledger/fabric-orderer:latest	orderer.example.com	"orderer"	20 minutes ago	Up 20 minutes	0.0.0.0:7050->
7050/tcp						
4d2ee1671567	hyperledger/fabric-couchdb	couchdb2	"tini -- /docker-ent..."	20 minutes ago	Up 20 minutes	4369/tcp, 5984
/tcp, 9100/tcp, 0.0.0.0:9984->9984/tcp						
5538629f624a	hyperledger/fabric-orderer:latest	orderer3.example.com	"orderer"	20 minutes ago	Up 20 minutes	0.0.0.0:9050->
7050/tcp						
9424c7f5d01b	hyperledger/fabric-couchdb	couchdb0	"tini -- /docker-ent..."	20 minutes ago	Up 20 minutes	4369/tcp, 9100
/tcp, 0.0.0.0:5984->5984/tcp						
569e3f77b89b	hyperledger/fabric-orderer:latest	orderer5.example.com	"orderer"	20 minutes ago	Up 20 minutes	0.0.0.0:11050->
>7050/tcp						
0dec31613bb6	hyperledger/fabric-couchdb	couchdb1	"tini -- /docker-ent..."	20 minutes ago	Up 20 minutes	4369/tcp, 5984
/tcp, 9100/tcp, 0.0.0.0:7984->7984/tcp						
f432ad14ee3b	hyperledger/fabric-couchdb	couchdb3	"tini -- /docker-ent..."	20 minutes ago	Up 20 minutes	4369/tcp, 5984
/tcp, 9100/tcp, 0.0.0.0:11984->11984/tcp						
9bca8e4b085f	hyperledger/fabric-couchdb	couchdb5	"tini -- /docker-ent..."	20 minutes ago	Up 20 minutes	4369/tcp, 5984
/tcp, 9100/tcp, 0.0.0.0:15984->15984/tcp						

Figure 4. Docker containers.

```

2026-04-11 11:15:06.873 UTC [chaincodeCmd] chaincodeInvokeOrQuery -> DEBU 04b ESCC i
nvoke result: version: 1 response: <status:200 > payload: {"Procurement":"Highway co
nstruction Lot 2","TimeStamp":"2026-04-11 11:15:05.452","Bidder":"Compass Ltd","Bid"
:"1000",smartcontract endorsement:<endorser:"Org1MSP">
2026-04-11 11:15:06.873 UTC [chaincodeCmd] chaincodeInvokeOrQuery -> INFO 04c chainc
ode invoke successful. result: status:200

```

Figure 5. Writing to the blockchain.

```

2026-04-12 10:32:23.590 UTC [chaincodeCmd] chaincodeInvokeOrQuery -> DEBU 04b ESCC i
nvoke result: version: 1 response: <status:200 > payload: FOUND [ {"Key":"Id-XV2Bzm"
, "Record": {"Procurement":"Highway Construction Lot2","TimeStamp":"2026-04-11 11:15
:05.452","Bidder":"Compass Ltd","Bid":"1000"}}, {"Key":"Id-SD5Txc", "Record": {"Proc
urement":"Highway Construction Lot2","TimeStamp":"2026-04-11 11:11:22.713","Bidder":
"Compass Ltd","Bid":"1000"}}, {"Key":"Id-OL6Ysa", "Record": {"Procurement":"Highway
Construction Lot2","TimeStamp":"2026-04-11 11:08:16.932","Bidder":"Compass Ltd","Bid
":"1000"}}, ] smartcontract endorsement:<endorser:"Org1MSP">
2026-04-12 10:32:23.590 UTC [chaincodeCmd] chaincodeInvokeOrQuery -> INFO 04c chainc
ode invoke successful. result: status:200

```

Figure 6. Finding information from blockchain.

The presence of a special *cli* container for executing commands allows for efficient testing of the application code. Multiple command scripts have been created to execute various requests by calling methods of smart contracts. This facilitates the testing process by repeatedly executing them with different parameters in debug mode.

5. Discussion

Most governments are striving to modernize public services through transparent, secure and efficient digital infrastructures. That is why they are turning to solutions based on blockchain technologies. Blockchain technology can improve the process of conducting public procurement, as it inherently provides trust between participants, security of transactions, irrevocability and provability of actions, impossibility of tampering with already recorded data and clear registration of the moment of each event in the blockchain network. Key advantages of a blockchain-based e-tendering solution for public procurement include real-time auditing, reduced risks of corruption, increased trust of stakeholders and streamlined public procurement workflows.

This paper proposes a blockchain-based solution for conducting electronic tenders for public procurement, based on HyperLedger Fabric. Bulgarian legislation does not yet recognize the blockchain register as official evidence in court (similar to the paper protocol). Therefore, blockchain-based solutions currently duplicate records from blockchain to paper records to comply with the legislative framework. In this context, regarding legal and procedural compatibility, it can be argued that both the existing solution [10] and the proposed solution fully comply with the Bulgarian legislative framework for public procurement and do not require regulatory or legislative changes. The conceptual validation of the proposed solution is made with the network testing. Compared to the traditional web-based solution, it promises to provide greater transparency and efficiency in spending public funds, and achieves the set quantitative indicators (lowest price for the public resource) with automated evaluation and quality factors defined in the smart contract. However, like the classic solution, it does not eliminate the risk of “unrealistically low” prices, leading to a possible poorer quality of the order execution (cheaper materials, fewer personnel or less qualified personnel).

However, compared to the classic solution, in the blockchain-based solution the iterative procedure of finding a participant from the ranked offers who is ready to conclude a contract is automated by the smart contract and the time for concluding a contract with a contractor is assumed to be significantly shortened in such situations. Unfortunately, in both approaches the automated process cannot prevent a preliminary agreement between the participants on how far to lower the price or who will win this particular offer, which makes the tender meaningless for the state in specific areas with a small number of participants, since these agreements between the participants occur outside the steps of the tender procedure and are difficult to measure and verify with quantitative parameters.

The proposed blockchain-based solution for conducting e-tenders for public procurement will increase the transparency of the procedure by reducing certain technical and human-error risks during input, which is automated in the smart contract algorithm, which in the classic solution can disqualify a participant.

The authors envisage conducting future experimental studies that include detailed evaluations of the proposed system by implementing different scenarios to evaluate key metrics such as throughput of the transactions, latency under varying network conditions and computational overhead of deploying isolated channels for each procurement. While the current work presents a conceptual validation of the proposed solution through a virtual infrastructure, experimental studies will be performed with real infrastructure to obtain adequate results. At the same time, this also allow for more adequate testing for errors and boundary conditions and scenarios for parallel bidding.

The aim of the authors’ future research is to expand the proposed model by including a public blockchain, through which payments under auction procedures can be made automatically and without delay, since the private blockchain is not tied to a currency. The proposed solution can also be modified for other types of e-auctions, such as auctions for public sales conducted by a private enforcement agent (for debts to banks and credit companies) or for auctions for public sales by a state enforcement agent (to the relevant district court). In Bulgaria, in such an auction, by law the starting price is 80% of the real market value, and in many cases the real market value is not reached during the auction. Due to this fact the consignor may not receive the expected amount. Such a proposed blockchain-based solution would ensure the highest return of funds to the debtor in a fast and transparent manner, increasing his trust in the procedure.

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