


ET-DeaL: A P2P Smart Contract-based Secure Energy Trading for Smart Grid System

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Aparna Kumari ; Arpit Shukla ; Rajesh Gupta ; Sudeep Tanwar ; Sudhanshu Tyagi ; Neeraj Kumar All Authors

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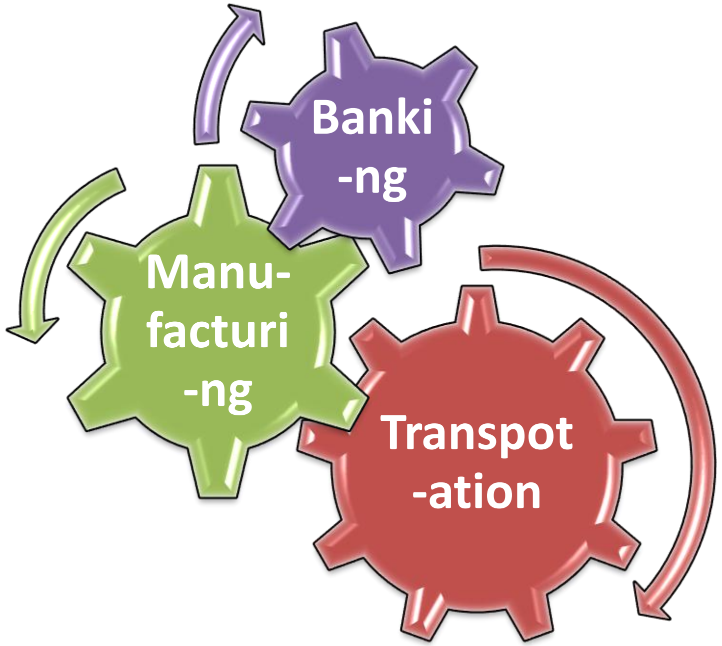
Motivation

Data-driven
Smart Applications



Energy demand

Energy: Driving force in various data-driven smart application

- India is at third place in energy production and consumption [1].
- The energy demand in India is escalating (predicted as 1894.7 TWh by 2022) as the nation is moving towards digitization [2].
- The usability of electronic devices have increased exponentially over the fixed energy generation sources leading to the shortfall of 0.7% of power supply during peak hours [2].

Smart Grid System

- Management of electricity by the traditional power grid is quite challenging. It distributes electricity to the consumers without knowing their needs leading to either surplus (wastage) or shortfall (demand) of electricity in particular regions.

- To overcome these issues, the traditional grids should become smart enough to sense the electricity requirements and distribute it efficiently.

- "Smart Grid" (SG) with the Internet of Things (sensors, controllers, and actuators) and advanced communication system is a viable solution to generate, transmit, and distribute the electricity efficiently.

SG: Traditional Energy Trading System

- SG system offers many services to the end-users, such as load management, load forecasting, and Energy Trading (ET).
- ET is the buying, selling and moving of energy (electricity and natural gas) from where it is produced to where it is needed.
- The traditional SG systems offer a centralized platform for ET to meet out the consumer energy demands, easy to design, deploy, and control system.
- The performance (computation and communication cost), latency, and reliability, of the traditional centralized SG system degrade with an increase in ET requests and consumer energy demands.
- Though many solutions exist for this problem in literature but these solutions are not adequate to handle security, privacy, latency, real-time settlement of ET.
- Data among different devices in SG environment flows through an open channel, i.e., Internet, so security and privacy always remains a challenging issue.

Blockchain: A viable solution

- It is a digital ledger, i.e., a chain of blocks, which securely maintains transactions and records.
- It reduces the maintenance cost and increases the data consistency and security.
- It is a distributed ledger system with enhanced trust, security, and immutable records that protects single point failure [11], [12].
- The trust in the BC-based ET system is achieved through smart contracts (SCs) which are self-executable and self-verifiable programming constructs [13].

Research Contributions

- There is a requirement to design a secure smart contract for decentralized energy management in the SG system.

- There is a requirement to design a unique data access mechanism based on InterPlanetary File System (IPFS) to achieve low latency and high throughput in SG data distribution.

- There is a requirement to design a system to facilitate the Electric Vehicles (EVs) owner to charge the EVs by buying energy from nearby prosumer (interested in selling energy) using ET-DeaL system.

ET-DeaL :The Proposed Scheme

- The ET-DeaL is proposed as a Smart Contract-based Secure Energy Trading scheme for SG system for peer-to-peer (P2P) ET. ET-DeaL uses Ethereum smart contract (ESC) and Inter Planetary File System (IPFS) for the P2P ET management.

- It manages the energy load of residential houses, industries, and electric vehicles (EVs).

- In ET-DeaL, security and privacy issues have been resolved using ESC, while storage cost issues are handled with IPFS protocol.

- A real-time ESC is implemented and deployed in Truffle suite. The security bugs of the ET-DeaL are tested on MyThril open-source tool.

- Finally, ET-DeaL performance evaluation demonstrates its effectiveness as compared to the traditional systems where it outperforms the existing schemes with respect to various performance evaluation metrics.

ET-DeaL :System Architecture

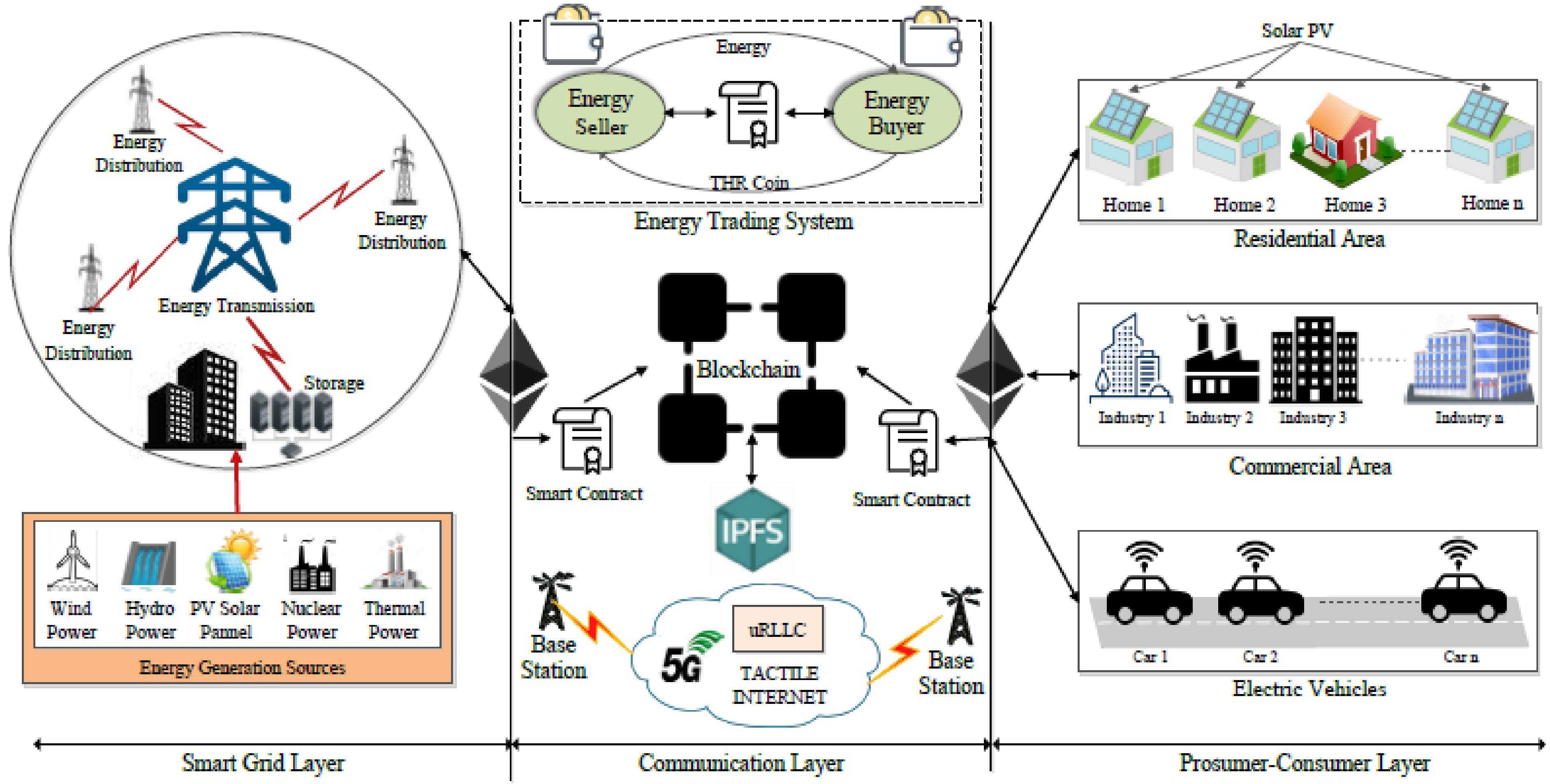


Fig. 2: *ET-DeaL* System Architecture.

SECURITY VERIFICATION OF ET-DeaL

- ET-Deal verifies several security features of ESC, for instance, tx.origin, re-entrancy, tx order dependence, and time-stamp dependence.
- It is essential to evaluate the security vulnerabilities of ESC before its final deployment in the blockchain as it cannot be changed later.
- Hence, the security vulnerabilities of ET-DeaL is tested by using the open source tool MyThril as shown in the snapshot of result [25].

```
jayshah2024@jayshah2024-HP-Pavilion-Notebook:~/.local/bin$ python3 myth analyze
eAuction.sol --solv 0.5.0
The analysis was completed successfully. No issues were detected.
```

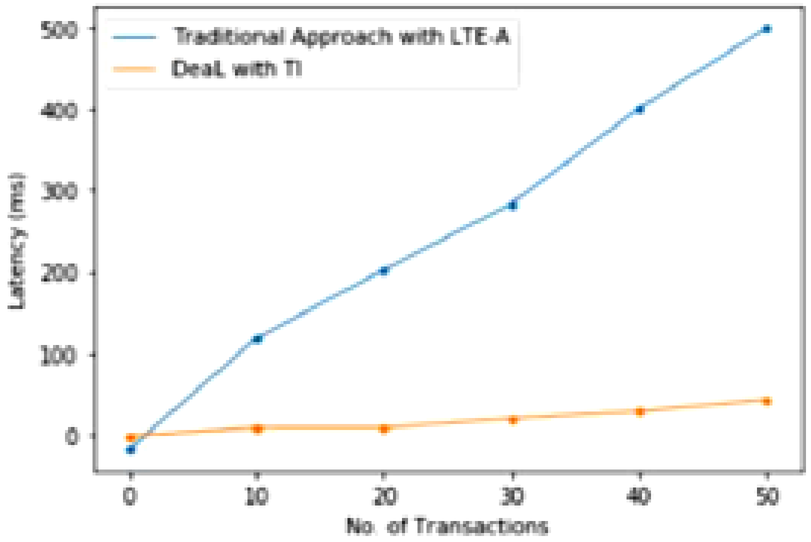
Formal security verification of ET-DeaL

Results and Discussion

A. Latency

- ✓ Based on the number of transactions, the latency was compared between the traditional vs. the proposed approach (Fig.).
- ✓ Here, we consider the communication network of ET-DeaL is 5G-enabled TI, whereas LTE Advanced in the case of a traditional approach.
- ✓ Linear regression of the calculated latency values of both methods was observed. It illustrates that the latency in ET-DeaL is relatively low as compared to the LTE-based traditional approach.

The ultrareliable low latency communications (URLLC) feature of TI manages to attain round trip latency of < 1ms, ($L_{5G\text{-}TI}$) < 1ms) with 99.999% of reliability as compared to the round trip latency of LTE Advanced, which is below 10ms, ($LTE_{Advanced} < 10ms$).



(a) Latency comparison.

Fig : Comparison of ET-DeaL and traditional approach

Results and Discussion

B. IPFS storage cost

- ✓ In the traditional Ethereum-based blockchain approach, the data stored on the blockchain itself, and it is costly.
- ✓ The proposed scheme, ET-DeaL uses a distributed IPFS mechanism to store energy data (relatively low-cost storage).
- ✓ ET-DeaL uses IPFS for energy data storage, which only involves the hash storage cost.

In the traditional Ethereum based blockchain approach, the data stored on the blockchain itself, and it is pretty costly, (≈ USD $550 for one word). ET-DeaL uses a distributed IPFS mechanism to store energy data, which is relatively low-cost and involves the hash storage cost only.

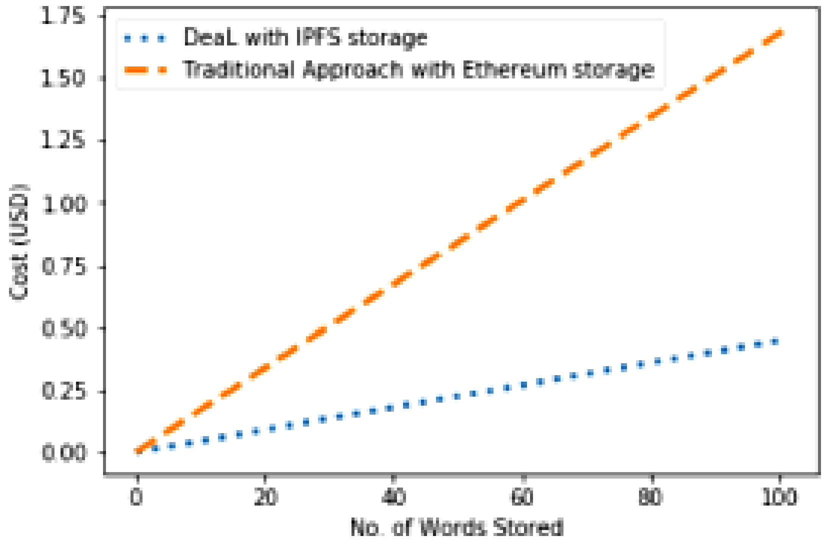


Fig : Comparison of ET-DeaL and traditional approach (b) Storage cost comparison.

Results and Discussion

C. Scalability

- ✓ The below figure shows the improved scalability based on the transaction time and the number of blocks mined during E-auction of the ET-DeaL vs. the traditional approaches (both BC-based and non-BC based).
- ✓ In ET-DeaL, 5G-enabled TI is used as communication medium to ensure the ultra-high reliability (i.e., 99.999%) and ultra-low latency (i.e., < 1ms).
- ✓ In ETDeaL, any user, i.e., consumer or prosumer is stored in IPFS database, and only the hash key is sent to BC. Hash-key size is 160 bits, which is less than original transaction size (in bytes).

ET-DeaL offers more transactions to be added to the chain at the same quantum of time, which provides services the more number of users, hence improving the overall scalability.

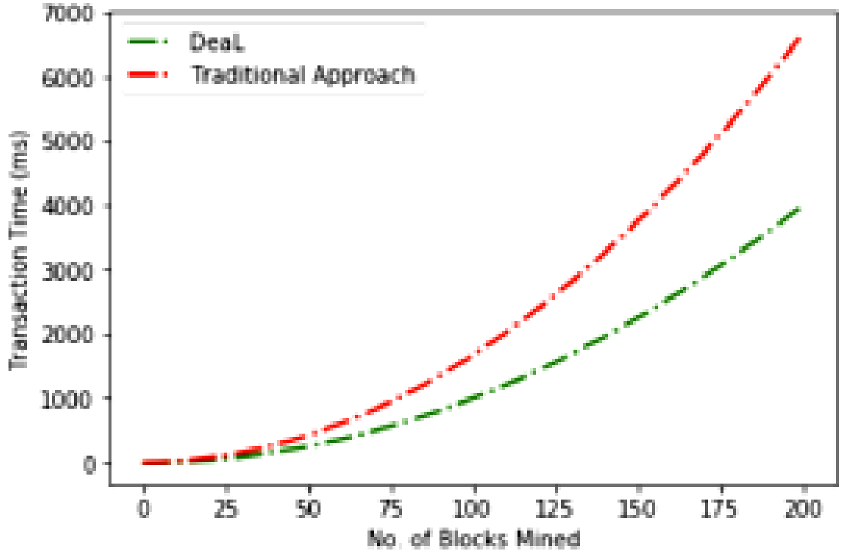


Fig : Comparison of ET-DeaL and traditional approach

(c) Scalability comparison.

Conclusion

- ✓ ESC with IPFS eliminates the need for a third-party.
- ✓ The deployment of ET-DeaL over Truffle suite and Remix IDE performs the block information verification.
- ✓ The communication latency is quite low by the use of IPFS storage system and 5G-TI in the proposed ET-DeaL scheme.
- ✓ The performance of ET-DeaL was better that traditional BC-based system on the basis of data storage cost and latency.
- ✓ The scalability of ET-DeaL on different platforms and its verification should be performed for the successful implementation of ET-DeaL in near future.
- ✓ To promote ecofriendly green energy.

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Thanks

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Mail ID: sudeep.tanwar@nirmauni.ac.in
Web Site: http://technology.nirmauni.ac.in/author/sudeep/
Mobile: +91-8392837867