Truthful Auction-Based Resource Allocation in Blockchain-Enabled Internet of Vehicles

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Overview

Blockchain

📜 **DISTRIBUTED LEDGER:**
DATA IS SHARED ACROSS MULTIPLE COMPUTERS (NODES) FOR TRANSPARENCY AND RELIABILITY.

🔒 **IMMUTABILITY:**
ONCE RECORDED, INFORMATION CANNOT BE CHANGED OR DELETED.

🌐 **DECENTRALIZATION:**
NO CENTRAL AUTHORITY — ALL PARTICIPANTS VERIFY TRANSACTIONS.

🧠 **SECURE BY CRYPTOGRAPHY:**
USES ENCRYPTION TO PROTECT DATA AND ENSURE TRUST.

Advantage Of Blockchain

- High Security
- Transparency
- Fast and Efficient
- Cost Reduction
- Traceability

• Mobile Blockchain

Combines **blockchain technology with mobile or moving devices**.

Each mobile device acts as a **node** to store and verify data.

Enables **secure, decentralized communication** between mobile users or vehicles.

Example: Internet Of Vehicles(IOV), Mobile Payment Systems, Decentralized Mobile Apps(DApps)

🌐 Cloud Computing Overview

- Cloud computing is a model that enables **on-demand access** to shared computing resources
- Resources include:
  - Servers
  - Storage
  - Networks
  - Applications
- Services are delivered over the **Internet**
- Users pay only for what they use
- Cloud Service Provider: Google GCP, Amazon AWS , Microsoft Azure

Types of Cloud Services

- **Infrastructure as a Service (IaaS)**
  - Virtual machines, storage, networking
- **Platform as a Service (PaaS)**
  - Development platforms and tools
- **Software as a Service (SaaS)**
  - Ready-to-use applications via browser

🌐 Edge Computing Service Provider (ECSP)

- **Edge-level computing provider** delivering CPU, storage, and network.
- **Processes data locally**, reducing latency.
- **Supports blockchain and IoT applications** with resources.
- **Bridges users and cloud**, acting as a nearby mini data center.

💰 Transaction Management

Refers to the **process of handling and verifying** transactions in the blockchain network.

Each transaction is **validated by miners or nodes** before being added to a block.

Ensures **accuracy, consistency, and security** of all recorded data.

Once confirmed, the transaction becomes **permanent and tamper-proof** in the ledger.

Auction System

Bidding-based mechanism for buying or selling resources.

Participants place bids to compete for limited assets.

Ensures **fair, transparent, and efficient allocation**.

Widely used in **blockchain and IoV** for resource management.

🏷️ Types Of Auction System

1. English Auction
2. Dutch Auction
3. First Price Auction
4. Second Price(Vickrey) Auction
5. Double Auction

Consensus

- **Agreement process** among all blockchain nodes.
- Ensures **only valid transactions** are added to the ledger.
- Maintains **one shared and trusted version** of the blockchain.
- Provides **security and reliability** in a decentralized network.

Types of Consensus Mechanisms

1. **Proof of Works(POW):**
   - Miners solve **complex puzzles** to validate transactions.
   - **High energy consumption** due to heavy computations.
   - Rewards miners with **cryptocurrency**.
   - Used in **Bitcoin**; secure but slower.

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2. Proof of Stake(POS)

- Validators are **chosen based on the number of coins they stake**.
- **Energy-efficient**; no complex puzzles like POW.
- Rewards are distributed **proportionally to the stake**.
- Used in **Ethereum 2.0, Cardano**, and other modern blockchains.

Problem Statement

- The rapid growth of the **Internet of Vehicles (IoV)** has increased the demand for real-time computation and blockchain-based services.
- Vehicles have **limited onboard computing resources** and must offload tasks to nearby **Edge Computing Service Providers (ECSPs)**.
- **Edge resources are limited** and shared among many competing vehicles, leading to resource contention.
- Existing **centralized resource allocation methods** lack transparency, fairness, and are vulnerable to manipulation.

Objective

- Efficient Resource Allocation
- Truthful Auction Design
- Weighted Resource Model
- Profit Optimization
- Blockchain Transparency

Literature Review

1. Blockchain technology enables **decentralized, transparent, and secure systems** without relying on trusted third parties, as first demonstrated in Bitcoin [1].
2. The introduction of **smart contracts** in Ethereum expanded blockchain applications by enabling automated and trustless execution of transactions [2].
3. With the growth of **Internet of Vehicles (IoV)**, researchers have explored blockchain integration to improve **security, trust, and data integrity** in vehicular networks [3].
4. Due to **limited onboard computing resources**, vehicles often offload computation to **edge computing service providers (ECSPs)**, making efficient resource allocation a critical challenge [4].
5. Traditional **centralized resource allocation mechanisms** suffer from lack of transparency, single-point failure, and vulnerability to selfish behavior [5].
6. **Auction-based and incentive-compatible mechanisms** have been proposed to address fairness and efficiency in resource allocation under strategic user behavior [6].
7. Recent studies demonstrate that **truthful auction mechanisms** can improve **social welfare, resource utilization, and fairness** in blockchain-enabled IoV environments [7].

Methodology

1. Constant-Demand Auction Mechanism (CDAM)

- Designed for **blockchain-based IoV systems** where all miners have the **same demand (di = 1)**
- **Objective:** Maximize **social welfare** through efficient resource allocation
- **Allocation:** Uses **Maximum Cost Maximum Flow Algorithm** for optimal distribution
- **Pricing:** Applies **Vickrey–Clarke–Groves (VCG)** mechanism to ensure **truthful bidding**

2. Multi-Demand Auction Mechanism (MDAM)

- Designed for **blockchain-based IoV systems** where miners have **different resource demands ($d_i \neq 1$)**
- Objective: **Maximize social welfare** while handling **variable resource requirements**
- **Problem type:** NP-hard (cannot find exact optimal solution in polynomial time)
- Uses **heuristic approach** for near-optimal performance

$$d_i = \alpha \cdot CPU_i + (1 - \alpha) \cdot Storage_i$$

Weighted Resource Model

- **Weighted Resource Calculation**
  - Each miner’s resource demand is converted into a single value
  - Combines CPU and Storage requirements using a weight factor
- **Formula:**

Where:
  - di : Weighted resource demand
  - α: Weight factor (0 ≤ α ≤ 1)
  - CPUi ,Storagei : Resource demands of miner *i*

Bid Density

- Bid density measures **value per unit resource**
- Used as the key metric for miner prioritization

Formula:

$$\text{Bid Density}_i = \frac{b_i}{d_i}$$

Where:

- bi : Bid value submitted by miner *i*
- di : Weighted resource demand

Allocation Mechanism

Determines **which miners receive resources**

Ensures **fair, efficient, and truthful allocation**

Operates after receiving bids from miners

Core component of CDAM and MDAM

Participants in Allocation

Miners (Vehicles):

Submit bids for computing resources

Have CPU and storage demands

Edge Computing Service Provider (ECSP):

Offers limited computing resources

Sets an asking price

Blockchain Network:

Records bids, allocation, and payments transparently

Allocation in CDAM

- All miners request **uniform resource demand**
- Miners are sorted by **bid value**
- Resources are allocated sequentially
- Ensures higher **miner satisfaction**
- Simple and computationally efficient

Allocation in MDAM

- Miners have **heterogeneous CPU and storage demands**
- Uses **weighted resource model**
- Miners are sorted by **bid density**
- Allocation ensures:
  - Resource feasibility
  - Bid density ≥ ECSP ask density
- Improves **resource utilization and efficiency**

Pricing and Payment Rule

ECSP Pricing Parameters

- ECSP announces an **ask value** based on resource cost

Ask Value:

$$A = CPU_{cap} \times CPU_{cost} + Storage_{cap} \times Storage_{cost}$$

- Ask density represents **minimum acceptable price per unit resource**

Ask Density:

$$AD = \frac{A}{\alpha \cdot CPU_{cap} + (1 - \alpha) \cdot Storage_{cap}}$$

$$p_i = \frac{(Bid\ Density_{\,i} + \ Ask\ Density)}{2} . d_i$$

Dataset Description

- **Miner Dataset**
  - CPU Demand
  - Storage Demand
  - Bid Value
  - Weighted Resource

Miner_ID	CPU_Demand	Storage_Demand	Bid_Value	Weighted_Resource	Bid_Density
M1	78	23	322.47	50.5	6.386
M2	112	48	141.86	80	1.773
M3	76	89	126.08	82.5	1.528
M4	158	24	108.94	91	1.197
M5	105	49	251.61	77	3.268
M6	56	91	159.65	73.5	2.172
M7	189	73	166.13	131	1.268
M8	200	55	342.83	127.5	2.689
M9	51	40	309.44	45.5	6.801

ECSP Dataset

- CPU Capacity
- Storage Capacity
- Cost per unit
- Ask Price

ECSP_ID	CPU_Capacity	Storage_Capacity	CPU_Cost	Storage_Cost	Ask_Value
E1	8270	2780	0.51	0.38	527.41
E2	6140	2850	0.87	0.5	676.68
E3	9560	3890	0.54	0.43	683.51
E4	5150	2730	0.61	0.45	437
E5	5130	3930	0.6	0.49	500.37

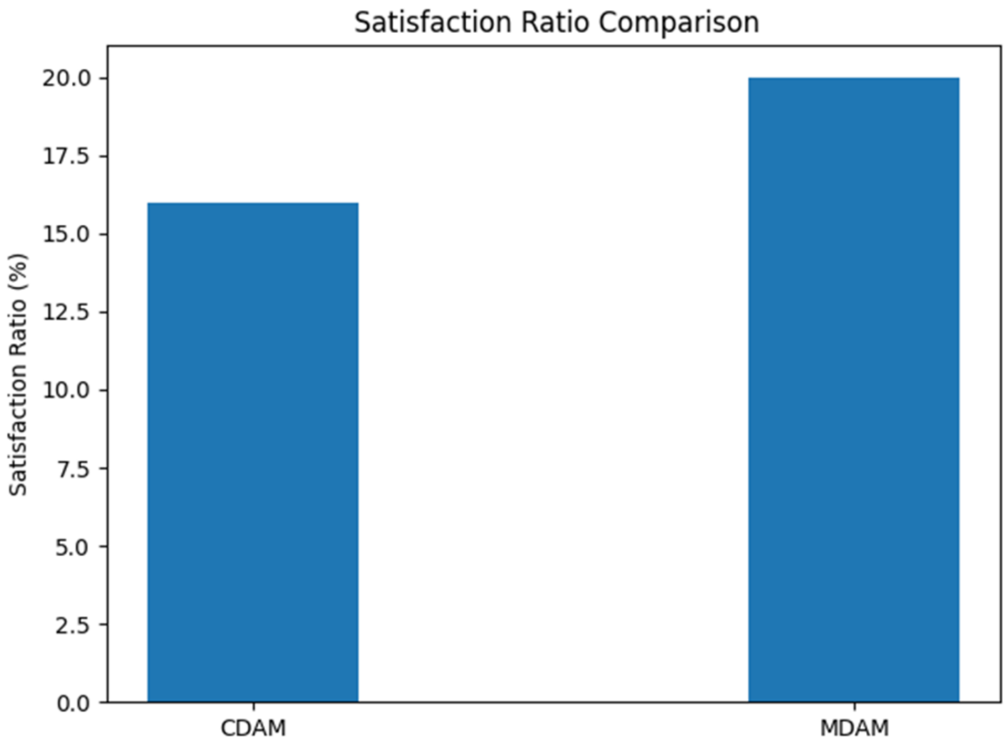
Connectivity Matrix

- $\Delta_{ij} = 1$ indicates that miner i can connect to ECSP j
- $\Delta_{ij} = 0$ indicates no possible connection.

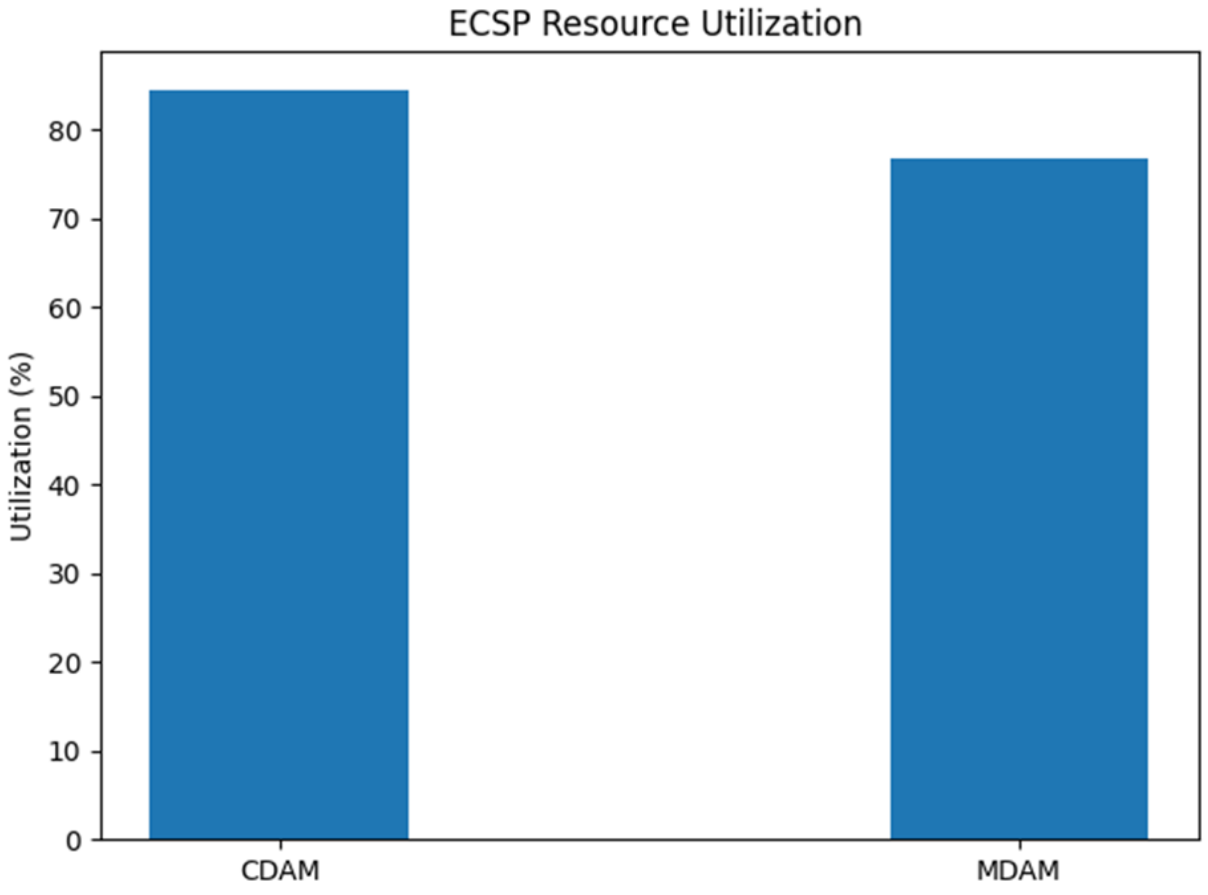
Miner_ID	E1	E2	E3	E4	E5
M1	0	1	1	0	0
M2	0	0	1	0	1
M3	0	1	1	0	0
M4	0	0	0	0	0
M5	0	0	0	0	0
M6	1	0	0	0	0
M7	0	0	0	1	1
M8	1	0	0	0	0
M9	0	0	0	1	0
M10	0	0	0	0	0
M11	1	1	1	1	0
M12	1	0	0	0	0
M13	0	0	1	0	0
M14	0	0	1	0	1

Result and Findings

1. Satisfaction Ratio Analysis



2. ECSP Resource Utilization



Conclusion

- Auction-based mechanisms effectively allocate resources in IoV
- CDAM and MDAM provide balanced performance
- Blockchain enhances transparency and trust
- Suitable for next-generation intelligent transportation systems

Future Work

Lightweight Consensus Mechanisms
Explore energy-efficient consensus protocols such as Proof-of-Stake or PBFT to reduce computational and energy overhead in blockchain-enabled IoV systems.

Mobility-Aware Resource Allocation
Incorporate real-time vehicle mobility and dynamic network conditions to improve allocation efficiency in highly dynamic IoV environments.

Multi-ECSP Cooperative Models
Extend the framework to support cooperation among multiple ECSPs for better scalability, load balancing, and fault tolerance.

Smart Contract Implementation
Implement the auction and payment processes using smart contracts to enhance transparency, automation, and trust.

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Thank You!!