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## The Development of Decentralized Ticketing System Using Web3

Yu-Xian Cheng<sup>1</sup>, Kah-Ong Michael Goh<sup>2\*</sup>, Check-Yee Law<sup>3</sup>, Connie Tee<sup>4</sup>, Yong-Wee Sek<sup>5</sup>, Md  
Ismail Hossen<sup>6\*\*</sup>

<sup>1,2,3,4</sup>Faculty of Information Science and Technology, Multimedia University, Jalan Ayer Keroh Lama, 75450 Melaka, Malaysia.

<sup>5</sup>Faculty of Artificial Intelligence and Cyber Security, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian  
Tunggal, Melaka, Malaysia.

<sup>6</sup>School of Information and Communication Technology, Griffith University, 170 Kessels Road, Nathan, QLD 4111, Australia.

\*corresponding author: (michael.goh@mmu.edu.my; ORCID: 0000-0002-9217-6390)

\*\*corresponding author: (m.hossen@griffith.edu.au; ORCID: 0000-0003-3632-937X)

*Abstract* - Traditional ticketing systems often suffer from major drawbacks such as ticket fraud, duplication, inflated resale prices, lack of transparency, and centralized control over transactions. These issues result in reduced trust and limited flexibility for both event organizers and ticket buyers, especially in unregulated secondary markets. To address these gaps, this paper presents the design and development of a Decentralized Ticketing System (DTS) using Web3 technologies. The system leverages Ethereum blockchain, smart contracts written in Solidity, and Non-Fungible Token (NFT)-based ticket issuance to ensure security, transparency, and verifiable ownership. Features include wallet-based login via MetaMask, multi-ticket purchasing, QR-based validation, controlled resale pricing, and seller revenue withdrawal. Smart contract reliability is enhanced using OpenZeppelin libraries and tested with Mocha and Chai. By decentralizing control and automating ticket processes, the proposed DTS enhances current practices by offering a more secure, tamper-proof, and user-centric ticketing alternative that mitigates fraud and enables transparent peer-to-peer interactions. The architecture of this system integrates a decentralized storage and interaction layer that connects the blockchain smart contracts with a web-based user interface which allow organizers to create events and sell tickets while buyers can securely browse, purchase, and manage their digital assets. The system also demonstrates how blockchain-based ticketing can improve traceability, reduce intermediaries, and support fairer event ecosystems for stakeholders across industry.

*Keywords*—Web3, Decentralized Ticketing, Non-Fungible Token, Blockchain, Smart Contract, MetaMask, Ethereum

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### 1. INTRODUCTION

In today's ticketing landscape, centralized ticketing systems which also refer to traditional ticketing system are widely mainstream in society because they are the ones who dominate the market [1], [2]. The centralized ticketing systems act as the intermediary between event organizer and seller, which permits them to control the price of tickets, flow of transactions, resale opportunities and so forth. This is precisely the problem with centralized ticketing systems. Firstly,

buyers are often at risk of purchasing fake tickets, especially in the secondary resale markets [3], [4]. Centralized ticketing systems generally lack reliable mechanisms to verify the authenticity of the pre-owned ticket which significantly increases the fraud cases that occur in the centralized ticketing systems. Secondly, the high transaction fees charged by centralized ticketing systems inflating the ticket prices for buyers while limiting the earnings for sellers [5]. Thirdly, all the activities that occur in centralized ticketing systems are non-transparent. The users of the system are unable to track the ticket availability, pricing and resale restrictions. This causes the system user to have confusion on the ticket status and leads to unfair practices [6], [7].

Furthermore, unregulated secondary markets in centralized ticketing systems often lead to skyrocketing ticket prices due to the lack of regulation or price caps on fares. As a result, buyers are compelled to purchase overpriced tickets to attend the events they wish to enjoy [3], [8]. Lastly, scalability issues are another pressing concern with the centralized ticketing platform. Most of these systems were unable to effectively manage the surge of users at instances of high demand. Ineffective management resulted in poor-quality user experience and degradation in user trust and satisfaction within the system [7].

In view of numerous common problems within centralized ticketing systems including ticket fraud, high transaction fees and lack of transparency, this causes buyers to accidentally buy counterfeit tickets from an unofficial secondary market [1] whereas sellers often lack freedom on controlling the price and transaction fees of their events [5]. These problems become even worse when pricing is unclear, and the system struggles to handle large numbers of users during peak or busy hours. Buyers not only may experience delays, failed transactions, and system crashes that lead to dissatisfaction and loss of trust [7], event organizers may also suffer financial losses and reputational damage due to poor user experience and the inability to ensure fair access to tickets during high-demand situations [6], [8].

To this end, these challenges have presented the essence of a need for an innovative, user-centred ticketing solution to be further elaborated on within the next section through delivery in the Distributed Ticketing System with the use of Web3 technology. This paper introduces a Decentralized Ticketing System (DTS) using Web3 technologies to overcome the limitations in Centralized Ticketing System. We aim to answer the research question: How can a Web3-based DTS improve the security, transparency, and fairness of event ticket transactions compared to traditional centralized systems? Thus, the research objectives include:

- 1) To examine how centralized ticketing platforms operate and identify weaknesses in preventing fake tickets in secondary resale markets.
- 2) To create a decentralized ticketing solution that offers lower transaction fee for users during the payment process.
- 3) To design a transparent ticketing platform that ensures all transactions and ticket ownership records are publicly auditable and tamper-proof.

By using blockchain and smart contracts, the system can provide a tamper-proof, transparent and efficient ticketing platform [1], [6]. Each ticket transaction can be openly checked by anyone which removes the need for middlemen in the process. User transactions are kept safe through MetaMask which uses Ethereum's secure signing methods to make sure the data is real and has not been changed [9], [10]. The communication through the application's web interface is protected by Secure Sockets Layer (SSL) and Transport Layer Security (TLS) encryption via HyperText Transfer Protocol Secure (HTTPS). The system allows users to register as either buyers or sellers. Sellers can create and manage events, while buyers can purchase, transfer or resell tickets. The smart contracts usage in this system is to manage the entire ticket process automatically. It helps to ensure fair ticket distribution and smooth user interactions in the system.

In contrast to most existing DTSs that predominantly address Non-Fungible Tokens (NFT) issuance, resale restrictions, or developer-focused frameworks, the envisioned DTS provides a more comprehensive ecosystem. It unifies both buyer and seller functions within one system, provides event organizers with an inherent on-chain method for withdrawing revenues, and allows transparent ticket lifecycle management through various phases. Furthermore, the DTS utilizes ERC-721 tokens for ownership verification and allows auditable fund flows. This provides an end-to-end solution that enhances usability, fairness, and accountability over previous decentralized ticketing approaches.

This study aims to improve the ticketing experience in a major way. It offers a secure, low-cost and scalable option compared to traditional systems. Section 2 presents the evolution and existing approaches in digital ticketing systems. This is followed by the research methodology used to develop the DTS in Section 3. Section 4 describes the system design and technical foundation. Section 5 explains the smart contract features and functional logic. Section 6

discusses how blockchain is integrated into the system architecture. Section 7 presents the results of the implementation, and the paper is concluded in Section 8.

## 2. LITERATURE REVIEW

### 2.1 Evolution of Digital Ticketing Systems

Ticketing systems have evolved significantly over time. They have shifted from manual, paper-based methods to highly digitized and centralized systems. While the centralized systems raised convenience and automation, they also came with several fundamental limitations such as vulnerability to fraud, lack of transparency, and lack of user control [1]. These drawbacks have catalysed the development of DTSSs, particularly those that leverage Web3 technologies including blockchain, NFTs, and smart contracts. Over time, digital ticketing evolved into more specialized categories. These include barcode-based and QR-code ticketing, mobile app ticketing, and cloud-based ticketing solutions. More recently, blockchain-based ticketing systems emerged as a response to the shortcomings of earlier models. These platforms promise enhanced security, ownership verification, and transparency through decentralization and cryptographic mechanisms [6].

### 2.2. Overview of Digital Ticketing Approaches

Modern digital ticketing systems can be classified into several types:

- 1) Centralized Ticketing Systems: These systems are operated by single entities and offer high speed. However, they lack transparency and are vulnerable to manipulation. [9].
- 2) Tracking-Based Systems: They utilize GPS, QR codes, or NFC for access control. However, they still depend on centralized infrastructure. [10].
- 3) Blockchain-Based Ticketing Systems: They use NFTs, smart contracts, and distributed ledgers to ensure immutability and ownership proof. They enable secure peer-to-peer exchange without intermediaries. [11].
- 4) Web3-Based Systems: They evolve from basic blockchain models, aiming for full decentralization and tokenization. These systems also emphasize identity management and user-centric control. [7].

### 2.3 Existing Work

One of the earliest major breakthroughs in this area is the use of NFT ticketing systems, as proposed by Jiang and Zhou [3]. Their system issues tickets using NFTs on a private blockchain, and this addresses issues such as counterfeiting, unauthorized resales, and secondary market price increases. Their smart contracts cap resale prices to avoid scalping and ensure fairness. Besides, the system allows tickets to be made into digital collectibles, further enhancing the user experience. Legacy payment methods like Alipay and WeChat were also accommodated to extend accessibility, especially in regions where the utilization of cryptocurrencies is restricted. Private blockchain infrastructure can lead to scalability issues during high demand times as a result of its validation procedures and limited openness.

In another project, SafeTicket, initiated in 2023 and researched by Gómez et al. [4], aims to facilitate ticketing transparency and security via the use of Ethereum-based NFTs. It allows peer-to-peer resale of tickets without intermediaries. SafeTicket enables identity verification through QR code scanning for real users only. Pilot implementation user feedback also revealed a high level of satisfaction with fraud prevention by the system. But the criticism also identified some areas for improvement, which included making the user interface more efficient and demonstrating blockchain functionality better for non-technical users.

Dhanvardini et al. [5] took a technical solution through a dApp-enabled ticketing system, developed with the Truffle Suite, Web3.js, and Ethereum smart contracts. The solution is focused on modular development so that developers deploy decentralized ticketing apps that are tailored to suit their requirements. This is an open, safe platform for exchanging tickets without central control. However, due to its technologically focused design and exclusive reliance upon cryptocurrency, the architecture can be less appealing to non-technical end users and regions with regulatory prohibitions against crypto payments.

In contrast, Mandoliya et al. [8] developed a privacy-focused, standardized ticketing system for public transportation. It integrates NFT digital identities with zero-knowledge proofs (ZKPs), enabling selectively revealing private information during ticketing transactions. User credentials are kept in NFT-encoded QR codes, and anonymity as well as security are guaranteed through ZKP mechanisms. The structure ensures interoperability between various transport providers and prefers user agency of personal data. Despite these advances, widespread adoption is arguably hindered by a lack of blockchain literacy and by legal restrictions on cryptocurrency in certain regions.

In order to bridge the gap between existing Web2 platforms and Web3 functionality, WebTTCOM, proposed by Yu et al. [12], implements a hybrid ticketing system. It offers a backend interpreter module that translates Web2 API calls into Web3-compatible formats, offering transparent interfacing with existing infrastructure. It offers support for Hyperledger Fabric for attribute-based access control (ABAC), enabling only authorized users to view sensitive on-chain information. Smart contracts manage data storage, management, and API generation. While highly scalable and flexible, the complexity and deployment price of WebTTCOM may deter adoption by low-scale organizations with little technical expertise.

Collectively, these works display a wide variety of decentralized ticketing architectures with various strengths and weaknesses. NFT models focus on collectability and verification; mobile-first systems like SafeTicket focus on ease of use; tech frameworks like dApps focus on developer ease; and hybrid systems like WebTTCOM focus on enterprise-scale integration. These developments collectively reflect the growing trend towards secure, transparent, and accessible ticketing solutions enabled by Web3 technologies.

#### *2.4 Gaps in Literature*

Previous research has explored different mechanisms of building decentralized ticketing platforms, including NFT platforms [11], decentralized applications (dApps) [5], and hybrid Web2-Web3 setups [12]. Nonetheless, most of the critical challenges remain to be addressed thoroughly. Such challenges include scalability, security, usability, regulatory compliance, and user acceptance. Whereas individual research has proposed modest solutions to the mentioned issues, there is very limited end-to-end research that addresses the above areas simultaneously under a solid and accessible DTS.

First, scalability continues to be a technical limitation. Current blockchain platforms like Ethereum cannot handle large volumes of ticket transactions during high-demand times, affecting performance and user experience [7]. While ideas like sharding and sidechains have been floated, implementing them without compromising on decentralization

Secondly, security vulnerabilities in smart contracts render systems vulnerable to hacking and money loss. Despite the presence of tools for auditing and formal verification, studies show that most decentralized systems are susceptible to bugs and logical errors [13]. There is also a problem of privacy with public ledgers leaking user data at times [14], [15]. This necessitates further research in topics such as ZKPs to further secure user data.

Third, usability stands in the way of mainstream adoption. The majority of decentralized systems are not user-friendly for non-technical individuals, with requirements of wallet knowledge, private key management, and Web3 interfaces. Although WalletConnect and MetaMask offer integrations in numerous tools, the chasm in user experience is far from being bridged [2], [9].

Regulatory compliance is another aspect that has not been given adequate investigation. Running a decentralized system across different countries with laws like General Data Protection Regulation (GDPR), Anti-Money Laundering (AML) laws, and tax laws is challenging, especially when working with off-chain data and verifying user identity [16]. There are not many research studies that offer adaptable frameworks that balance decentralization and legal responsibility.

Lastly, there is scarce user uptake due to unfamiliarity and distrust of Web3 technologies. Although transparency and fairness are promoted as advantages, users are not keen to transition from established systems without ample incentive, education, or assurance. Despite the promise of DTSs in delivering transparent, secure, and user-oriented platforms, the literature proves patchwork solutions with rare attention to the complete user lifecycle. This research aims to bridge these gaps by covering both the technical issues and the human factors involved. The goal is to help develop a more secure and inclusive DTS.

### 3. METHODOLOGY

This study follows an Agile-based development approach to design and implement a DTS using Web3 technologies. The development was carried out iteratively through planning, system design, implementation, testing, and deployment phases. Every phase prioritizes transparency, decentralization, and automation using blockchain smart contracts and NFT-based ticketing. Agile methodology was used because of its accommodation of flexibility to address changing requirements and incorporation of feedback. The system was built incrementally in several sprints with continuous improvement and verification at each phase. Figure 1 illustrates the overall development process. The lifecycle framework enables adaptive project management and is thus well-suited for DTS development.



Figure 1. Agile-based Development Lifecycle of DTS

This study follows an Agile-based development approach to designing and developing a DTS with Web3 technologies. This aims to address issues in centralized ticketing systems, such as fraud, lack of transparency, and minimal control for users. This will be achieved through the utilization of smart contracts and NFTs on the Ethereum blockchain. The research methodology is structured across several stages: requirement gathering, system planning, prototype development, testing, and deployment.

The first stage involves establishing the scope and technical feasibility of implementing NFT-based ticketing on a decentralized platform. This includes identifying key functional requirements such as user registration, event creation, ticket purchase using cryptocurrency, ownership transfer, and peer-to-peer resale. Ethereum was selected as the underlying blockchain due to its strong support for smart contracts and NFT standards like ERC-721. MetaMask was chosen to manage user wallet authentication and facilitate secure transactions, while front-end development relied on standard web technologies including HTML, CSS, and JavaScript.

Once requirements were clearly defined, the system architecture was designed to reflect a modular and layered approach. Four main layers were identified: the frontend layer for user interaction, the integration layer for communication with blockchain through Web3.js, the smart contract layer for business logic execution, and the blockchain layer for immutable data storage. Solidity was used to develop the smart contracts that manage the entire process of tickets—from creating and checking them to transferring and reselling them. These contracts were tested and deployed on the Ethereum Sepolia Testnet. The deployment was done using the Hardhat framework.

During development, the Agile method helped improve the system step by step through regular testing and ongoing feedback. Functional testing was employed to confirm critical features like ticket release and resale, while integration testing confirmed smooth interaction between the frontend interface and the smart contracts deployed. Security testing was conducted with tools like MythX, Slither, and OpenZeppelin to detect probable vulnerabilities like reentrancy and overflow bugs. Performance and usability were also tested to confirm that the system continued to be accessible and efficient during simulated real-world scenarios.

The last deployment of the prototype was integrating the front-end interface with the deployed smart contracts using contract ABI and address. Integration with MetaMask allowed real-time wallet interaction for buying and transferring tickets. Documentation and user manuals were also created to guide future developers and users. The process was aided by tools like Node.js for backend functionality, Alchemy for stable RPC connection, and GitHub for version control. The approach guarantees the DTS prototype meets the fundamental concepts of decentralization, transparency, and empowering users, laying a solid groundwork for future scalability and adoption.

## 4. SYSTEM DESIGNS AND TECHNICAL FOUNDATION OF THE DTS

The DTS realized in this work utilizes Web3 technologies to remove central intermediaries and offer a secure, transparent, and tamper-proof solution for event ticketing. Based on the Ethereum blockchain, the system employs smart contracts for automating ticket issuance and verification, and NFTs for encoding ticket ownership in the form of verifiable, transferable tokens [1], [6]. The combination of these technologies solves perennial issues in conventional ticketing websites like double-spending, fraudulent resales, and limited control for users. This section presents the key features and components that constitute the basis of the DTS.

### 4.1 Decentralized Infrastructure

The DTS relies on the Ethereum blockchain, which is a decentralized and immutable public ledger [6]. Unlike the traditional centralized one-server or authority ticketing system, the DTS distributes ticket ownership and transaction history across multiple nodes. The decentralized setup makes ticket information always available, fully transparent, and protected from tampering. It gives event organizers, buyers, and validators access to the information independent of a single platform.

### 4.2 Verifiable NFT-Based Ticketing

Each ticket on issue in the DTS is issued as a unique NFT according to the ERC-721 standard [3]. When an NFT is minted and assigned to a buyer's wallet, its ownership details are recorded immutably on the blockchain. This provides immutability: no single authority is able to change, copy, or cancel the ticket without applying the mutually agreed contract reasoning. All changes in ownership and resales are written as blockchain transactions, so there is a traceable record of all transfers of tickets.

#### 4.2.1 Regulatory Considerations and Compliance Strategy

Under the EU's Markets in Crypto-Assets Regulation (MiCA), the majority of unique NFTs fall outside the regulations. Nonetheless, NFTs created in large series or that behave like standard tokens can be regarded as crypto assets. Those may require cybersecurity audits meeting standards comparable to CompTIA Advanced Security Practitioner (CASP+) certification. National regulators already support this pragmatic approach. For example, Austria's FMA has stated that NFTs created on a large scale or split into fractions may still fall under MiCA, even if they are labelled as "NFTs." [17]. Meanwhile, the GDPR applies to any personal data handled during ticketing [18].

The UK financial-promotions regime for "qualifying crypto assets," which is policed by the FCA, has stringent regulations on how tokens can be promoted to retail consumers. Some NFTs that are purely for collection purposes may be outside of these regulations, but platforms need to carefully consider their functionalities and not imply any investment returns. The Advertising Standards Authority (ASA) also points out that crypto advertisements should be fair, clear, and not misleading [19].

In Malaysia, NFT ticketing systems operate within the scope of the Securities Commission's Digital Assets Guidelines that set out the boundaries for the use of blockchain tokens in innovative applications. The Personal Data Protection Act (PDPA) 2010 also protects the prudent handling of personal data obtained through the process of purchasing tickets. It supports the use of secure off-chain storage combined with on-chain referencing for transparency. In parallel, Bank Negara Malaysia recognizes digital assets as a valid mode of digital innovation and promotes their use in solutions like event ticketing subject to the incorporation of approved payment gateways [20].

### 4.3 Autonomous Execution via Smart Contracts

Smart contracts within the DTS are liable for automating major operations like event creation, ticket minting, buying, transfer, and resale [5]. Such contracts exist fully on-chain and run preestablished rules without the need for human involvement. For example, as soon as a user pays the specified amount in ETH, the smart contract mints an NFT automatically and transfers it to the buyer's wallet. In the same manner, resale parameters like price caps or transfer

timings can be enforced by the contract directly, increasing fairness and eliminating the need to rely on third-party moderation.

#### 4.4 Wallet-Based User Interaction

Users interact with the DTS through a Web3-enabled browser that interfaces with the blockchain via MetaMask. MetaMask is a wallet extension that manages digital keys and securely signs transactions [21]. This facilitates secure and auditable identity verification independent of the need for usernames and passwords. Purchasers are able to engage directly with the smart contract to sell or buy tickets, and sellers can post events and view sales activity in real time. Decentralization is enabled to its fullest potential by putting users in direct control of assets.

#### 4.5 Real-Time Transparency and Traceability

The system is entirely dependent on the existing blockchain, and therefore ticket information is accessible to all. It contains information about ownership and recent purchase history, which are simple to verify and in real-time. Such transparency deters fraud, encourages responsibility, and makes checks simple at the point of entry to events. Event promoters can validate tickets using the existing blockchain ledger, and purchasers can ensure that their transactions are safe and irrefutable.

## 5. SMART CONTRACT FEATURES AND FUNCTIONAL LOGIC

### 5.1 NFT Ticket Minting

The smart contract allows for the automatic minting of NFT tickets as soon as a buyer makes a valid payment. Every ticket is minted on the ERC-721 standard and includes metadata like event ID, ticket type, and expiry time. The process ensures uniqueness, verifiability, and traceability.

Figure 2 illustrates:

1. Buyer initiates the `purchaseTicketsBatch()` function with ticket parameters.
2. Smart contract validates event activity, expiry, ticket supply, and price consistency.
3. For each ticket:
  - a. A new ticket ID is generated.
  - b. The NFT is minted using `_mint()`.
  - c. Metadata is assigned using `_setTokenURI()`.
  - d. Ownership and event details are stored in the tickets mapping.
4. Payment is transferred to the seller's balance.
5. Overpayments, if any, are refunded to the buyer.

The samples of pseudocode representation and description are as follows:

```
function purchaseTicketsBatch():
  for each ticket in request:
    validate event, expiry, availability
    require payment == expected price
    _mint NFT and assign token URI
    store ticket data in mapping
    emit TicketPurchased event
  refund excess ETH if overpaid
```

#### Description

Blockchain: Responsible for validating transactions, minting NFTs, and ensuring payment integrity.

DTS Smart Contract: Manages ticket minting logic, metadata assignment, and payment handling.

Overview of the Process Simplified: Buyer sends ETH → Validate event and ticket → Mint NFT → Record on-chain.

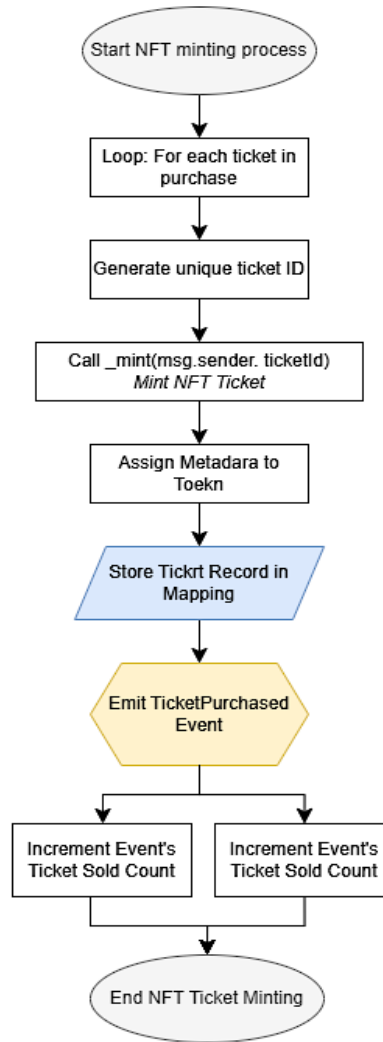


Figure 2. NFT Ticket Minting Process

### 5.2 Event Creation and Ticket Type Management

When a seller creates an event in the DTS, the system saves all the event details on the Ethereum blockchain. This includes the event name, date, location, ticket limits, and whether resale is allowed. This ensures that the event information is immutable and publicly verifiable. Ticket types are defined by specifying price and supply constraints, which are stored on-chain as part of the event's state. These definitions enable dynamic ticket allocation and ensure each ticket category is transparently accounted for. Any change in ticket supply or price is verified and carried out by the smart contract under limitations such as resale limits or time constraints. All event and ticketing data is managed through smart contracts, making it permanent and unchangeable. This eliminates the risk of data being changed or controlled by a single authority. Blockchain creates a shared record that works without needing trust between parties. It gives full transparency to both organizers and buyers.

#### Description

Blockchain: Immutably stores event and ticket configuration information.

Smart Contract: Verifies input, handles supply logic, and automatically enforces constraints.

Overview of the Process Simplified: Record event metadata → Define ticket categories → Enforce pricing/supply logic on-chain.

### 5.3 Ticket Resale and Transfer

When a resale is triggered, the ticket is briefly put on-chain with a price set by the seller. The smart contract ensures rules are obeyed, such as keeping the resale price to the original amount. It also ensures only valid, unused tickets can be resold. Ownership is transferred openly on the blockchain upon confirmation of payment. Transfer operations need to adhere to some rules, such as expiry dates, who can receive the ticket, and restrictions to avoid scalping. These include cooling-off periods and daily transfer limits, all of which are executed directly on the blockchain. By using smart contracts for these actions, the system ensures fair trading, keeps records clear for audits, and blocks any unauthorized changes. Buyers can trust that every resale and transfer is safe, trackable, and controlled only by code.

#### Description

Blockchain: It keeps ticket resales open and easy to track by clearly showing listings and permanently recording every change in ownership.

Smart Contract: It automatically checks resale rules, records who owns the ticket, and makes sure any transfer limits are followed.

Overview of the Process Simplified: List the NFT ticket for resale → Enforce resale rules → Complete the ticket transfer → Update ownership on-chain.

### 5.4 Ticket Validation and Scanning

The DTS employs smart contracts for automating ticket verification at the time of event entry. Every ticket, distributed as an NFT, has a `usesLeft` attribute to keep a count of remaining entries. When the `scanTicket()` function is called by the seller, the system verifies ticket validity, expiration, and use count. If the ticket is found valid and within limits, `usesLeft` is incremented. After being depleted, the ticket is set to invalid to avoid reuse. This workflow removes the need for manual checking and provides tamper-proof verification using on-chain logic.

#### Description

Blockchain: Keeps track of usage history and creates irreversible validation records.

DTS Smart Contract: Validates and updates ticket status.

Overview of the Process Simplified: Verify NFT → Reduce uses → Mark invalid if done.

### 5.5 Purchase Limitation and Anti-Bot Protection

To maintain fairness and secure the system against bots or spam attacks, the DTS smart contract includes a purchase limit regulation. A registered buyer can purchase a maximum of five tickets for an event per day. The regulation prevents malicious users or bots from grabbing multiple tickets. It also reduces the possibility of denial-of-service attacks and ensures fair availability for actual buyers. The limit is verified directly on the blockchain, and any request to surpass the permitted limit is automatically rejected by the smart contract.

#### Description

Blockchain: It stores and enforces purchase limit records for each buyer.

DTS Smart Contract: It validates each purchase request, verifies whether the daily limit has been reached and blocks any transactions that exceed it.

Overview of the Process Simplified: Buyer requests to purchase a ticket → Check against the daily limit → Approve if  $\leq 5$  → Reject if the limit is exceeded.

## 6. INTEGRATION OF BLOCKCHAIN IN DTS

This section describes the incorporation of blockchain in the DTS to render an open, secure, and fully independent event ticketing experience. Web3 technology deployment such as smart contracts, NFTs, and decentralized wallets ensures end-to-end trust, verifiability, and user control of the ticketing process.

### 6.1 System Architecture Overview

The architectural framework of DTS is organized into four primary layers as in Figure 3 as follows:

- Frontend Layer: Built with HTML, CSS, and JavaScript, it is the user interface that buyers and sellers interact with. It is interfaced with MetaMask for wallet authentication as well as transaction signing.
- Integration Layer: Uses Web3.js to connect the frontend to the Ethereum blockchain. It handles transaction preparation, smart contract calls, and status checking.
- Smart Contract Layer: Written in Solidity, smart contracts enforce business logic such as event creation, ticket issuance, validation, and resale. These contracts operate independently, without central intervention.
- Blockchain Layer: Powered by Ethereum Sepolia Testnet, this layer records all event, ticket, and transaction data immutably, providing a tamper-proof audit trail.

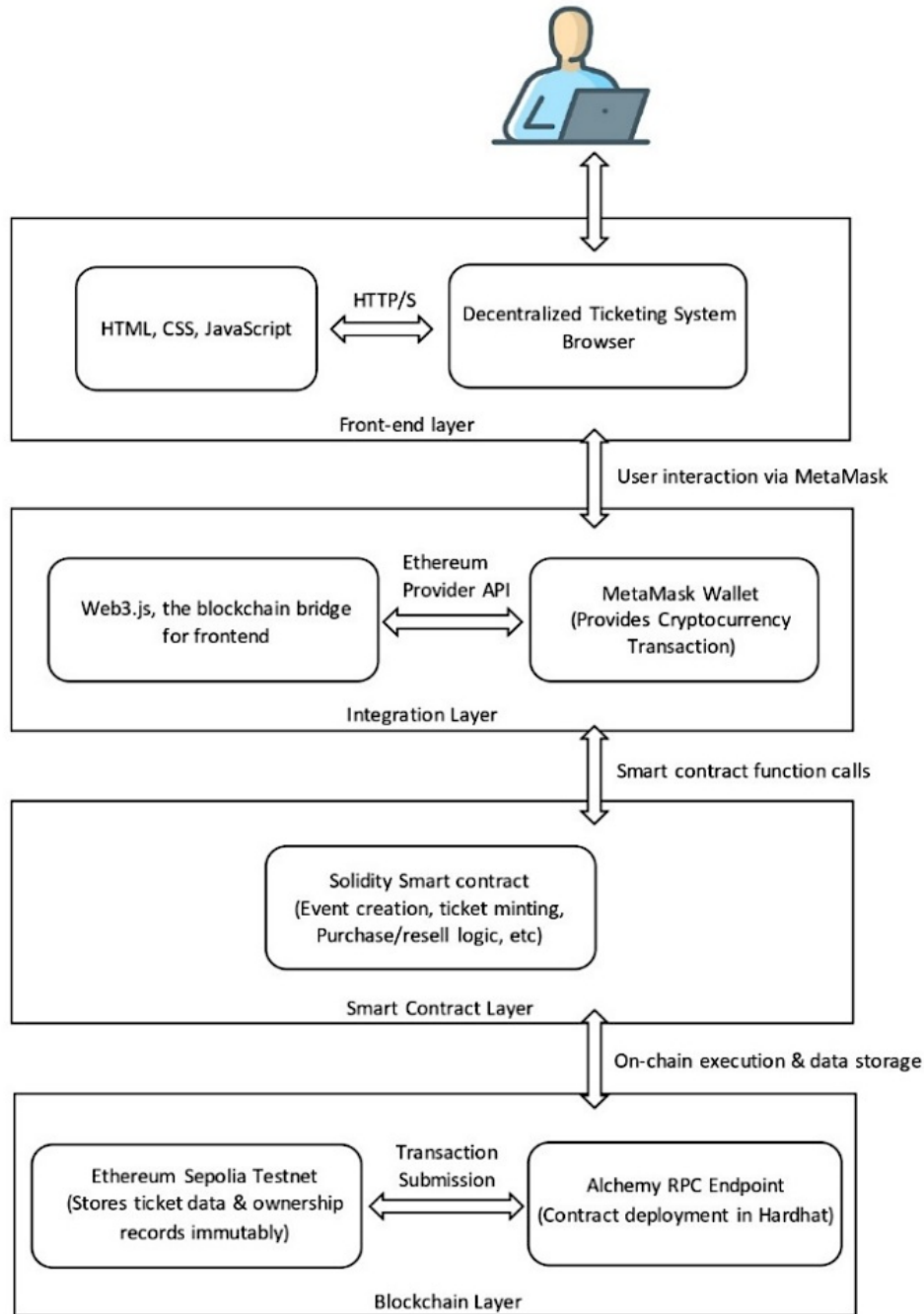


Figure 3. System Architecture Consisting of Four Layers - Front-End (HTML, CSS, Javascript), Integration (Web3.Js, Metamask), Smart Contract (Solidity), And Blockchain (Ethereum Sepolia Testnet)

## 6.2 Ticket Lifecycle Flow and Blockchain Coordination

The DTS operates fully on-chain, ensuring transparency, traceability, and trust through smart contract execution. The ticket lifecycle involves several coordinated steps between users and blockchain infrastructure as illustrated in Figure 4.

Below are the key stages and transitions involved:

1. **Event Creation:** The seller initiates the process by submitting event metadata such as event name, venue, date, and description. This metadata forms the basis for the event and will later be committed to the blockchain.
2. **Smart Contract Deployment:** Upon event creation, the system broadcasts a blockchain transaction to deploy an event-specific smart contract or call a factory contract. This contract governs all logic related to ticket types, purchases, ownership, and validation.
3. **Event Metadata Registration:** The submitted metadata is saved permanently, directly on the blockchain.
4. **Ticket Type Configuration:** The event organizer uses the deployed contract to define ticket types (e.g., Regular, VIP) along with their pricing, quantities, and rules. This configuration enables the smart contract to later accept purchases for each defined type.
5. **Purchase & NFT Minting:** Once the sale is enabled, buyers can purchase tickets. Upon confirmed payment, the system executes a blockchain transaction that mints an NFT representing the ticket and transfers it to the buyer's wallet.
6. **Transfer and Resale:** Buyers may transfer or resell their NFT tickets within the rules set by the smart contract. Ownership changes are handled via on-chain transactions, and the system emits events to update the public ledger. The ticket is then reassigned to the new owner and marked as ready for entry validation.
7. **Validation:** At the event venue, the ticket is scanned through a validator system. The smart contract checks whether the ticket is owned by the presenter, unused, and linked to the correct event. If valid, the ticket's status is updated on-chain to prevent reuse.
8. **Immutable Record:** The outcome of the validation process is permanently recorded on the blockchain. A transaction is sent to mark the ticket as used and log the entry event, ensuring full transparency and auditability for all stakeholders.

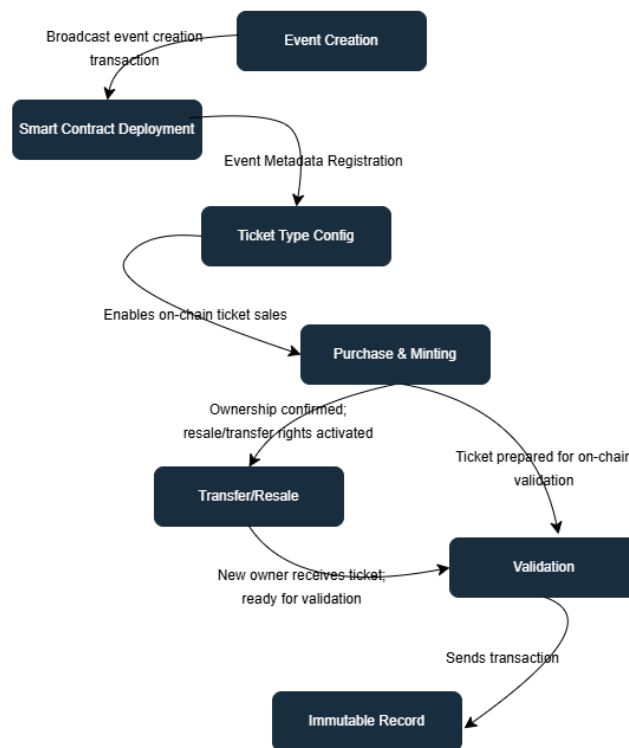


Figure 4. DTS Ticket Lifecycle and Blockchain Interaction Flow

### 6.3 Smart Contract Automation and Design Features

Smart contracts in DTS as in Figure 5 automate core ticketing operations and enforce platform policies:

- **Dynamic Minting:** NFTs are created only upon confirmed purchase and encoded with event, owner, and ticket type details.
- **Resale Restrictions:** Only unused tickets can be resold, with price caps enforced to prevent scalping.
- **Transfer Control:** Transfers are monitored with cooldowns and daily limits to reduce abuse.

These automated features remove the need for centralized administrative control and help guarantee fairness, traceability, and auditability across the platform.

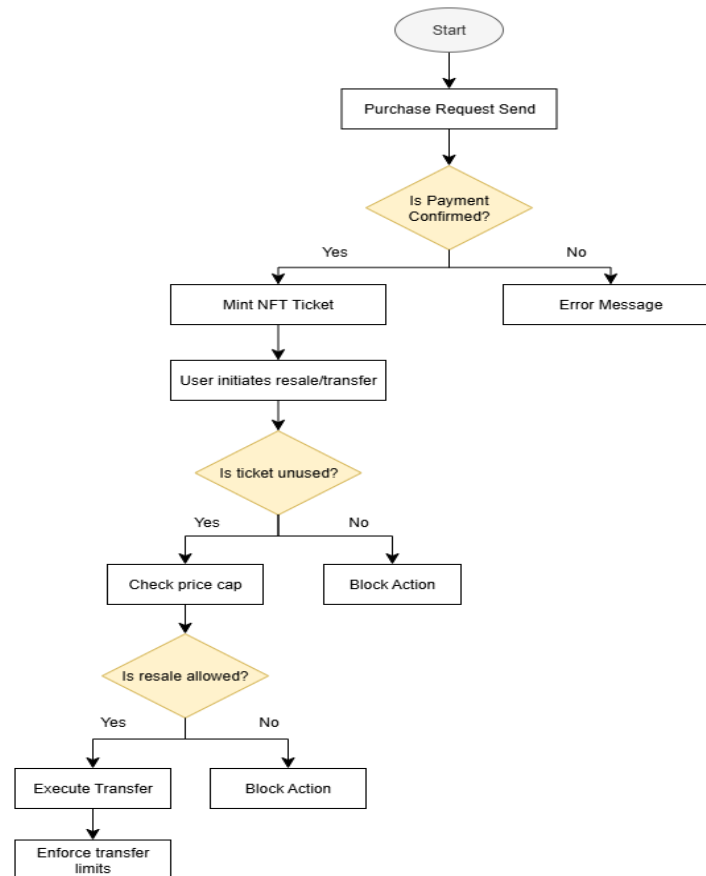


Figure 5. Smart Contract Automation Flow for Ticketing Operations in DTS

Based on Figure 5,

1. Buyer initiates a purchase request for a ticket.
2. The smart contract checks whether payment has been confirmed on-chain.
3. If payment is confirmed:
  - a. The minting function is triggered to generate a new NFT ticket.
  - b. Event ID, ticket type, and buyer ownership details are stored in the NFT metadata.
4. If payment is not confirmed, the smart contract returns an error message, and the process ends.
5. The buyer may initiate a resale or transfer request through the platform.
6. The smart contract checks whether the ticket is still unused.
7. If the ticket is used, the contract blocks the resale or transfer action.
8. If the ticket is unused:
  - a. The smart contract verifies that the resale price does not exceed the platform's predefined price cap.

- b. If the price cap is violated, the action is blocked.
  - c. If within limits, the smart contract checks whether resale is currently.
  - d. If resale is allowed, the ticket is transferred to the new buyer.
9. After a successful transfer, the smart contract enforces transfer limits to prevent abuse.

#### 6.4 Transparent Data Storage and Auditability

All essential transactional records and event-related data within DTS are stored immutably on the Ethereum blockchain. When a user creates an event, purchases a ticket, transfers ownership, or scans a ticket, a corresponding transaction is initiated and permanently written into the blockchain ledger. These transactions include hashed references and state changes governed by smart contract logic, making the data cryptographically secure and resistant to tampering. The blockchain is open to the public, so anyone can view the data. This means users, event organizers, and auditors can trace the entire history of a ticket. Fraudulent activities, such as double spending or unauthorized transfers, can be easily identified by comparing ownership states across block heights. This real-time auditability strengthens transparency and allows the system to self-verify user actions without a central authority.

#### 6.5 Wallet-Based User Authentication and Interaction

User access and participation are managed entirely through decentralized wallets:

- MetaMask Integration: Users sign in using Ethereum wallet addresses.
- Cryptographic Signing: Every interaction requires transaction approval, securing user intent.
- Decentralized Identity: No central account system or sensitive data storage is required.

Users do not create usernames or passwords. Instead, they authenticate by connecting their Ethereum-compatible wallet—MetaMask. Every sensitive interaction such as logging in, purchasing a ticket, or initiating a transfer requires explicit signature approval from the user's wallet. This cryptographic signing mechanism proves user identity without relying on a centralized account system. All activity is conducted directly between the user and the smart contract, ensuring privacy, ownership, and security.

Figure 6 shows the wallet-based authentication and interaction flow. The user begins by initiating a wallet connection request from their browser. This prompts MetaMask to authorize access and return the wallet address to the platform. Upon user approval, any action requiring authentication results in a signed transaction being sent to the smart contract. The DTS frontend then fetches on-chain data from the smart contract to reflect the outcome and update the user interface accordingly. At no point sensitive user data is stored or managed by a centralized server, ensuring a fully decentralized interaction model.

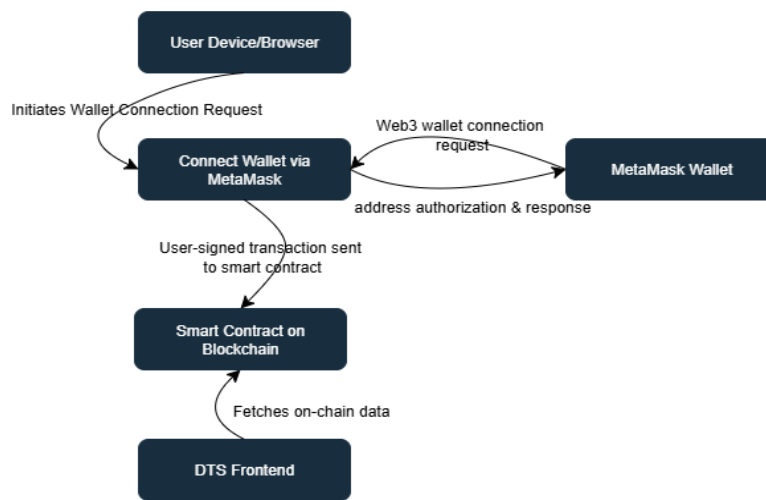


Figure 6. Wallet-Based Authentication and Decentralized Interaction Flow in DTS

## 7. RESULT

The DTS was successfully implemented and deployed on the Ethereum Sepolia Testnet, and its performance was evaluated based on the completion and functionality of core features. The system demonstrated effective execution of all critical operations through smart contracts, delivering a fully decentralized and transparent ticketing environment. Each feature was tested rigorously in simulated real-world scenarios to validate correctness, automation, and compliance with business rules.

Event creation and management allowed sellers to register and configure event metadata, including date, location, expiry, and ticket categories. The blockchain ensured that all event data was stored immutably and remained verifiable. Ticket purchases were processed securely through on-chain transactions, and NFT-based tickets were minted using the ERC-721 standard. These tokens were uniquely bound to the buyer's wallet, with each transaction recorded transparently on the blockchain. The ticket scanning functionality allowed event organizers to confirm ticket ownership and remaining usage in real time. Upon every scan, the smart contract incremented the use counter and invalidated tickets when depleted.

Resale and transfer activities were also processed successfully on-chain. Tickets could be transferred or resold among users with policy enforcement of strictures like resale caps, ownership validation, cooldowns, and transfer approval. All changes in ownership were updated in real-time and irreversibly on the blockchain. Seller withdrawals of accrued revenues were also supported by the system and were conducted securely without reentrancy vulnerabilities being introduced. Buyers could check their ticket portfolios at any moment, with all information—event metadata, ticket category, and consumption—being fetched from decentralized storage. In sum, the DTS realized consistent, autonomous enforcement of all ticketing workflows via smart contracts with complete traceability, immutability, and integrity of operations. Not only did the blockchain infrastructure secure every transaction, but it also maintained a publicly accessible audit trail that effectively minimized fraud risks and removed reliance on centralized intermediaries.

### 7.1 Transaction Throughput

Throughput was measured by interacting with the system on the Sepolia Testnet using Hardhat scripts. A batch of transactions was executed concurrently to observe how many could be processed within a period of time.

- **Test Configuration:** 50 transactions were submitted at the same time for Event ID 18.
- **Result:** The message "execution reverted: Max 5 tickets per event" was returned by the system. This indicates that the business logic of the smart contract effectively prevented transactions exceeding the maximum number of tickets.
- **Analysis:** Throughput testing was limited due to the contract regulations, but it indicated that the purchase limits were respected appropriately. To obtain improved throughput results, subsequent tests must modify the setup by distributing ticket purchases across multiple users without exceeding the 5-ticket limit.

### 7.2 Latency

Latency was defined as the duration from transaction submission to confirmation on the blockchain. Average confirmation latency on Sepolia varied from 10 to 12 seconds based on network congestion. This latency is normal in Ethereum testnets and is a function of the underlying block time and gas prioritization.

### 7.3 Transaction Fee Analysis

Transaction fees were tracked during ticket purchase attempts made through MetaMask on the Sepolia Testnet.

- **Gas Used (per purchase attempt):** approximately 65,000 – 70,000 gasses.
- **Gas Price (Sepolia testnet):** fluctuated between 20–25 gwei during testing.
- **Network Fee:** ~0.0004 ETH per transaction (testnet ETH, not real cost).

## 8. CONCLUSION

The Web3-based DTS was created to address prevalent problems in conventional ticketing systems. These problems span from ticket counterfeiting, centralized ownership and opacity to unjust prices in ticket resale. DTS allow users to buy and sell ticket directly without the needs of intermediaries. This makes each transaction easier to trace and safer for everyone involved.

The system was built using smart contracts that were written in Solidity and deployed to the Ethereum Sepolia Testnet via Hardhat. The frontend was developed using HTML, CSS, and JavaScript. A clear layered architecture is used to separate different parts of the system including the frontend, integration, smart contract and blockchain layers. This design helps keep the system organized and efficient. MetaMask is used for wallet-based login which removes the need for a traditional username and password. Web3.js links the website to the Ethereum blockchain and enables real-time interaction with smart contracts.

DTS introduces advanced smart contract functionality in terms of event creation, configuring ticket types, buying tickets in bulk, ticketing minting through NFTs, on-chain verification through QR scan, managing revenue, resale management and anti-spam protected transfers. Security functions such as access control, reentrancy protection and validation checks were implemented to achieve robustness and avert abuse. OpenZeppelin libraries were also included to provide greater contract reliability. All testing and deployment were carried out on the Sepolia Testnet with Alchemy that used as the blockchain gateway provider.

While the system was successful, some limitations were noticed. Firstly, the DTS presently operates only on the Ethereum Sepolia Testnet and has not yet been deployed on the Ethereum mainnet, where real transaction fees and network constraints would apply. Secondly, mobile responsiveness partially functioned because of the support limited to a few devices, and the system does not yet include features such as multi-currency payments, ticket refunds, or comprehensive event analytics. Lastly, the user adoption could be hindered by technical complexities in configuring a Web3 wallet such as MetaMask, particularly by users who lack exposure to blockchain technologies.

To improve and enlarge the system, several enhancements are proposed. Firstly, implementing the DTS on the Ethereum mainnet or Layer 2 chains such as Arbitrum or Polygon would increase functionality and reduce gas fees. Secondly, optimizing the system for mobile use and creating a dedicated mobile app would open it up to a greater number of users. Also, incorporating features such as refundability of tickets, loyalty rewards, analytical event dashboards, and integration of fiat payment gateways would render the system far more usable and encourage wider adoption. Lastly, conducting thorough security testing and providing more education for users could strengthen trust in the platform and encourage greater engagement. In conclusion, this study has shown that decentralized systems can provide secure and fair ticketing. It also demonstrates the ability to translate blockchain concepts into a functional and user-friendly application.

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## AUTHOR CONTRIBUTIONS

Yu-Xian Cheng: Conceptualization, Data Curation, Methodology, Validation, Writing – Original Draft Preparation;  
Kah-Ong Michael Goh: Project Administration, Writing – Review & Editing;  
Check-Yee Law: Project Administration, Supervision, Writing – Review & Editing;  
Connie Tee : Supervision, Writing – Review & Editing;  
Yong-Wee Sek: Supervision, Writing – Review & Editing;  
Md Ismail Hossen: Review & Editing.

## CONFLICT OF INTERESTS

No conflict of interests were disclosed.

## ETHICS STATEMENTS

Our publication ethics follow The Committee of Publication Ethics (COPE) guideline. <https://publicationethics.org/>

This research did not involve any human participants, animal experiments, or data collected from social media platforms. Therefore, ethical approval and informed consent were not required.

## DATA AVAILABILITY


Data availability is not applicable to this paper as no new data were created or analysed in this study.

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## BIOGRAPHIES OF AUTHORS

	<p><b>Yu-Xian Cheng</b> is currently pursuing a Bachelor of Information Science and Technology with a major in Security Technology at Multimedia University, Malaysia. Her academic interests include web development, secure system design, blockchain applications and decentralized technologies. She is passionate about leveraging emerging technologies to solve real-world problems, with a strong focus on system security and user-centric solutions. She can be contacted at email: 1201103724@student.mmu.edu.my / chengyuxian16@gmail.com.</p>
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	<p><b>Kah-Ong Michael Goh</b> is an associate professor at Multimedia University with over 23 years of experience. His expertise includes biometrics, pattern recognition, image processing, machine learning, AI, and cybersecurity. He has published over 70 international journal and conference papers and led R&amp;D projects with grants exceeding RM 2 million. His work has earned awards from ITEX, RICES, and international innovation platforms. His research focuses on multimodal biometrics, computer vision, cybersecurity, and intelligent systems. He serves as a reviewer for several ISI-indexed Scopus journals and is a Senior Member of the IEEE. He can be contacted via email at michael.goh@mmu.edu.my.</p>
	<p><b>Check-Yee Law</b> is a lecturer at Faculty of Information Science and Technology (FIST), Multimedia University (MMU), Melaka, Malaysia. Subjects taught include Information Systems Development, Human Computer Interaction, E-Marketing, Computer Concepts and Applications, and Mathematical Techniques. Her research interests span the fields of teaching and learning to development of systems, software, and mobile applications. Topics of interest include but are not limited to educational technology, human computer interaction, visual analytics, smart farming, user-centered design, Internet of Things (IoT), mobile computing, information systems, etc. She can be contacted via email at cylvaw@mmu.edu.my.</p>
	<p><b>Connie Tee</b> received both the MSc (IT) and PhD (IT) degrees from Multimedia University in 2005 and 2015, respectively. She is a Professor in the Faculty of Information Science and Technology Multimedia University since 2021. She is currently holding the position of the Dean of the Institute for Postgraduate Studies. Her research interests include computer vision, machine learning, deep learning and image processing. She is a senior member of the IEEE. She can be contacted via email at tee.connie@mmu.edu.my.</p>
	<p><b>Yong-Wee Sek</b> is a researcher at the Faculty of Artificial Intelligence and Cyber Security (FAIX), Universiti Teknikal Malaysia Melaka. His research interests include technology adoption, information systems, e-learning, Internet of Things (IoT), mobile computing, smart farming, and supply chain innovation. He has published in high-impact journals such as IEEE Access, IET Computer Vision, and AI Open. In addition, he actively contributes as a reviewer for journals including IEEE Access, F1000, and Brain Informatics. For collaboration or inquiries, he can be contacted via email at ywsek@utem.edu.my.</p>
	<p><b>Md Ismail Hossen</b> is currently pursuing the Ph.D. degree in computer science with Griffith University, Australia. His expertise lies in image processing and big data analysis, with a particular focus on agricultural applications. In addition, he serves as a Lecturer with American International University, Bangladesh. Outside of academia, he cherishes spending quality time with family and friends and enjoys traveling to enrich his understanding of diverse cultures and perspectives. He can be contacted via email at m.hossen@griffith.edu.au.</p>