# CA 6001I – Developing Blockchain Systems

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Blockchain based ecommerce application

# Introduction

In today's globalized marketplace, the efficiency and transparency of supply chains are paramount for businesses aiming to maintain a competitive edge. Supply chain management involves the coordination of various interconnected processes, from procurement and production to distribution and delivery, spanning across numerous stakeholders. However, traditional supply chain systems often suffer from inefficiencies, lack of transparency, and susceptibility to fraud and errors. Enter blockchain technology – a revolutionary solution reshaping the landscape of supply chain management[1].

Blockchain, the decentralized ledger technology originally devised for Bitcoin [2], has emerged as a game-changer in the supply chain domain. By leveraging blockchain, supply chain participants can establish a secure, immutable, and transparent record of transactions and product movement from raw material sourcing to the end consumer. Each transaction or event in the supply chain is recorded as a block on the blockchain network, creating an indelible chain of custody[1]. This distributed ledger ensures that all parties involved have access to the same information in real-time, fostering trust and accountability across the supply chain ecosystem. Moreover, the cryptographic nature of blockchain ensures data integrity and guards against tampering or unauthorized alterations, enhancing the overall security of the supply chain.

Blockchain technology offers several key benefits for supply chain management, including enhanced traceability, streamlined processes, reduced costs, and improved compliance with regulations and standards[1]. By providing a decentralized and transparent platform for tracking and verifying goods' origins, blockchain enables companies to mitigate risks related to counterfeit products, ethical sourcing, and supply chain disruptions. Furthermore, smart contracts, programmable code deployed on blockchain networks, automate and enforce contractual agreements between parties, facilitating smoother transactions and reducing administrative overhead[1][3]. Overall, blockchain technology holds the potential to revolutionize supply chain management, driving efficiency, transparency, and sustainability across industries worldwide.

# Use case description and discussion of its suitability

The supply chain use case presented in the demo application ‘de-centra’ exhibits a compelling integration of blockchain technology, particularly through the utilization of smart contracts, to facilitate various operations within the supply chain ecosystem.

At its core, the application serves as a platform akin to an e-commerce website, where producers can create and register their products for sale, we call them items, and interested buyers can subsequently purchase these items. What distinguishes this platform is the underlying blockchain infrastructure, which orchestrates the entire supply chain process transparently and autonomously. This is a very simple e-commerce scenario, stripped to a few basic operations commonly found in any e-commerce platform: creation, purchase, delivery, and tracking. However, it effectively demonstrates the usability of blockchain and smart contracts in facilitating these functions seamlessly, without the need for a central authority, operating within a trustless environment.

The integration of smart contracts into the supply chain workflow streamlines and automates many crucial aspects of the process. For instance, when producers create items, they input essential attributes such as name, price, category, and condition. These details are encoded into smart contracts, ensuring that the information is immutable and transparently recorded on the blockchain. This not only establishes a clear record of the item's origin and characteristics but also eliminates the need for centralized intermediaries to validate or verify the authenticity of the product.

Moreover, the functionality of the smart contracts extends beyond mere listing and purchasing. Once an item is sold, the creator of the item can initiate the dispatch process, thereby changing the item's state on the blockchain to "dispatched." This state transition is executed through a blockchain transaction, providing an auditable and tamper-proof trail of the item's movement within the supply chain. By leveraging smart contracts for these operations, the application ensures that transactions are executed reliably and autonomously, without the need for manual intervention or oversight.

Another notable feature of the de-centra application is the ability for users to freely track the status of items as they traverse the supply chain. This transparency is a hallmark of blockchain technology, enabling anyone to verify the current and final state of an item without relying on third-party intermediaries. This level of transparency not only enhances trust among supply chain participants but also helps mitigate risks associated with counterfeit products, unethical sourcing practices, and supply chain disruptions.

Overall, this is a basic application which can be extended further to include complex sub-processes and further stages of the supply chain, catering to the evolving needs of businesses and industries. As supply chain management continues to evolve, there is immense potential to enhance the functionality of the application by incorporating additional features such as quality control checkpoints, inventory management, logistics optimization, and sustainability tracking. Furthermore, the flexibility of blockchain technology allows for seamless integration with other emerging technologies such as Internet of Things (IoT) devices and artificial intelligence, enabling real-time monitoring and predictive analytics capabilities. By continually iterating and expanding upon the foundational principles demonstrated in this application, businesses can unlock new efficiencies, reduce costs, and mitigate risks across the entire supply chain spectrum.

# Roadmap for Supply Chain Management Application

The development of our Supply Chain Management Application is structured into five distinct phases, each aimed at enhancing the platform's functionalities, user experience, and industry impact. This roadmap outlines the key milestones and objectives for each phase, guiding our journey towards creating an efficient, transparent, and resilient supply chain ecosystem.

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Figure 1. Project Roadmap

## Phase 1: Proof of Concept and MVP Development

* Define project scope, objectives, and target user personas.
* Conduct market research and analysis to identify industry-specific requirements and pain points.
* Finalization and evaluation of technical stack and technologies.
* Design the architecture, user interface, and basic functionalities of the application.
* Develop smart contracts for essential operations such as item creation, buying, dispatching, and tracking.
* Implement basic blockchain integration and transaction handling capabilities.
* Build a minimum viable product (MVP) with core features for item listing, purchasing, and tracking.

## Phase 2: Testing and Iteration

* Conduct rigorous testing of the MVP to identify bugs, usability issues, and performance bottlenecks.
* Gather feedback from early adopters, stakeholders, and industry experts to refine the application.
* Iterate on the design, functionality, and user experience based on testing results and feedback.
* Optimize smart contracts, blockchain integration, and security measures for efficiency and reliability.
* Enhance documentation and user support resources to facilitate adoption and usage.

## Phase 3: Feature Expansion and Scalability

* Expand the range of features and operations supported by the application, addressing advanced supply chain management needs.
* Integrate additional functionalities for quality control, inventory management, logistics optimization, and compliance monitoring.
* Implement support for multi-chain or interoperable blockchain networks to enhance scalability and flexibility.
* Develop APIs and SDKs to enable seamless integration with third-party systems, services, and emerging technologies.
* Enhance user experience with personalized dashboards, notifications, and analytics insights for data-driven decision-making.

## Phase 4: Integration with Emerging Technologies

* Explore integration opportunities with emerging technologies such as Internet of Things (IoT), artificial intelligence (AI), and machine learning (ML).
* Implement IoT sensors and devices for real-time tracking of physical assets, environmental conditions, and supply chain events.
* Leverage AI and ML algorithms for predictive analytics, demand forecasting, and supply chain optimization.
* Enhance data security and privacy measures to protect sensitive information generated by emerging technologies.
* Collaborate with industry partners, research institutions, and technology providers to stay at the forefront of innovation in supply chain management.

## Phase 5: Continuous Improvement and Maintenance

* Establish processes for ongoing maintenance, support, and updates to ensure the application remains secure, reliable, and up-to-date.
* Monitor key performance indicators (KPIs) and user feedback to identify areas for improvement and optimization.
* Continuously iterate on the application based on evolving user needs, regulatory requirements, and technological advancements.
* Foster a culture of innovation, collaboration, and continuous improvement within the development team and across the supply chain ecosystem.

# Implementation

The De-centra application seamlessly integrates with the Metamask wallet to facilitate transactions. Items can be easily created with essential attributes such as Name, Value, Category, Condition, etc. Each item represents an individual entity with a unique contract address, which holds its associated value. The creation process incurs a gas fee in ether, which varies depending on the network's current usage. This mechanism can be refined in the future to adopt a more practical approach, such as implementing a fixed price for item creation. Initially, the Metamask account used to create the item automatically assumes ownership of that item. However, there is potential for future enhancements to introduce role-based access, allowing administrators or privileged accounts to perform specific operations.

The application offers four fundamental operations typical of any supply chain application: Creation, Buying, Dispatching, and Tracking. Once an item is created, another Metamask account can be used to purchase the item at its specified value in ether. The buying process entails both the item's value and a gas fee (value + gas). Presently, the item's address holds its value, but future iterations may transfer the value directly to the owner's wallet address.

Upon transaction confirmation in the Metamask wallet, the smart contract marks the item as sold and transitions its state to ready for dispatch. Subsequently, only the owner's account is authorized to dispatch the item once satisfaction is confirmed, Dispatch is also treated as a transaction on blockchain and would incurr a gas fee from the owner's account. Nevertheless, anyone can freely track the current state of the item in the supply chain anytime without incurring any fees. Thanks to Solidity's low-level calls.

The underlying smart contracts incorporate several validations to ensure robust and error-free transactions. For instance, in the event of a failed operation or transaction, users receive instant full refunds to their wallets. Consequently, the application provides trust and non-repudiation in a trustless environment, eliminating the need for third-party involvement.

In conclusion, the De-centra application exemplifies the power of blockchain and smart contracts in simplifying and securing supply chain operations. By seamlessly integrating with the Metamask wallet, users can create, buy, dispatch, and track items with ease. The application's robust smart contracts ensure error-free transactions and instant refunds in case of any issues, fostering trust and reliability in a decentralized ecosystem. As the application continues to evolve, potential enhancements such as role-based access and direct value transfer to wallets promise to further streamline processes and enhance user experience. Overall, De-centra sets a strong foundation for future innovations in blockchain-based supply chain management.

* The code is available on the GitHub repository - [*https://github.com/vsdcu/supply-chain-demo/tree/main*](https://github.com/vsdcu/supply-chain-demo/tree/main)
* A video with the presentation of the solution can be found on YouTube –
* Frameworks and tools

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Figure 2. Technology & Tools

Application consist three smart contracts based on Solidity programming language.

* *ItemManager.sol*

This smart contract is the main contract which provides the following functionalities.

* *Item creation*
* *Buying an item*
* *Payment handling*
* *Payment refunds*
* *Dispatching*
* *Tracking*
* *Item.sol*

This contract represents an Item entity. It handles the various attributes related to an Item. It also maintains the relationship of an Item with its item manager to handle the funds as each item is an individual entity in the solution and can be seen as an independent entity.

* *MyOwnableContract.sol*

Extension of the OpenZapllin ownable contract to provide the access and ownership management

The application is implemented using several frameworks to facilitate the development process.

* *Truffle:* This is a toolbox for Ethereum development, creation, and deployment of smart contracts.
* *Ganache:* That is the Ethereum local network that makes it easy to deploy and test the smart contracts.
* *React:* This is a JavaScript framework to build the front-end application.
* *HTML/CSS:* Used for the webpage and layout of the application.
* *Solidity:* Programming language to create the smart contracts.
* *Metamask:* Wallet provider for confirming transactions.
* *Openzapplin:* Provides standard audited contracts to handle common use-cases like ownership.
* *VS-Studio code:* IDE of choice for the implementation.

Following are a few screenshots of the de-centra application.

A screenshot of a computer

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Figure 3. Application Home page

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| Figure 4. Create new item form | Figure 5. MetaMask transaction confirmation | Figure 6. Validations and notifications |

# Discussion and Analysis

De-centra application demonstrates a significant advancement in supply chain management, leveraging blockchain technology and smart contracts to address key challenges in the industry. Through the implementation of blockchain, the application introduces transparency, traceability, and efficiency into supply chain processes, ultimately enhancing trust among participants and mitigating risks associated with counterfeit products, ethical sourcing, and supply chain disruptions.

One of the notable features of the application is its utilization of smart contracts to automate and enforce contractual agreements between parties. By encoding business rules and logic into smart contracts, the application streamlines transactions and eliminates the need for intermediaries, reducing administrative overhead and enhancing operational efficiency. This automation not only accelerates the pace of transactions but also minimizes the potential for errors and disputes, thereby improving overall supply chain reliability.

Moreover, the transparency enabled by blockchain technology ensures that all parties involved in the supply chain have access to the same information in real-time. This transparency fosters trust among stakeholders and enables greater accountability throughout the supply chain ecosystem. Participants can verify the authenticity and integrity of products at every stage of the supply chain, from sourcing to delivery, by accessing the immutable ledger maintained on the blockchain. As a result, the application empowers consumers to make informed purchasing decisions and holds suppliers accountable for their ethical and environmental practices.

Another key aspect of the de-centra application is its ability to track the movement of items along the supply chain. Through blockchain-based tracking mechanisms, users can monitor the status and location of products in real-time, facilitating timely decision-making and proactive risk management. This visibility into the supply chain not only enhances operational efficiency but also enables rapid response to potential disruptions or emergencies, minimizing the impact on business operations.

Furthermore, de-centra application serves as a scalable platform that can be extended to accommodate additional features and functionalities to meet evolving industry needs. As supply chain management continues to evolve, there is immense potential to enhance the application with advanced capabilities such as quality control checkpoints, inventory management, logistics optimization, and sustainability tracking.

In addition to the achievements in the de-centra supply chain application, it's crucial to acknowledge the significant challenges encountered during its implementation. Transitioning from the conceptualization stage to practical application revealed complexities inherent in integrating blockchain technology into supply chain management.

The obstacles encountered during the implementation process highlight the persistent need for refining and enhancing blockchain technology, particularly in terms of user experience and developer tools. The integration of smart contracts with front-end interfaces proved to be a significant challenge, necessitating developers to navigate through various IDEs and plugins to achieve seamless integration. For instance, my initial use of the Remix online IDE appeared promising due to its compatibility with its blockchain infrastructure like Shanghai Blockchain. However, I soon realized its limitations for end-to-end application development, prompting me to transition to a different development setup. Thankfully, tools like Ganache, Truffle, and Visual Studio Code emerged as a superior combination for full-stack application development locally. Ganache proved invaluable for spawning multiple wallet accounts on the locally running blockchain, while Truffle efficiently handled building, migrations, and contract publishing. Additionally, Visual Studio Code proved to be a versatile IDE for quick coding, whether in JavaScript or Solidity.

Nevertheless, overcoming these challenges serves as a testament to the resilience and ingenuity of developers in harnessing the potential of blockchain technology. By addressing these obstacles and refining development processes, the supply chain de-centra application lays the groundwork for future work in supply chain management and blockchain integration.

In summary, the de-centra application represents a significant step forward in revolutionizing supply chain management through blockchain technology and smart contracts. By enhancing transparency, traceability, and efficiency, the application addresses key challenges in the industry and empowers businesses to build more resilient and sustainable supply chains. While challenges and limitations exist, the potential benefits of blockchain adoption in supply chain management are substantial, paving the way for greater innovation and transformation in the industry.

# Application Improvements

De-centra application showcases a fully functional blockchain based ecommerce application with a limited set of functionalities. However, there are number of improvements under considerations for future work. A few of them are listed below -

*Enhanced User Interface:*

User interface of the application is very basic at the moment, this could be improved to make it more intuitive and visually appealing. This could involve refining the layout, adding graphical elements, and optimizing user flows to enhance user experience.

*Additional Item Attributes:*

Attributes related to the item can be expended, further users can provide custom attributes depending on the nature of item while creating items in the system. This would give richer experience to the users. Additional details such as product description, images, dimensions, and manufacturing information can be included which provides buyers with more comprehensive product information.

*Integration with Payment Gateways:*

Integration of payment gateways to facilitate seamless transactions and conversion of fiat money to cryptocurrencies within the application. This would enhance the buying experience and streamline the payment process, increasing user satisfaction and adoption.

*Integration with other wallets:*

Integration with other wallets is important for application robustness and allow users who don’t use the Metamask wallet to participate in it.

*Smart Contract Automation:*

There are further opportunities present to automate supply chain processes further using additional smart contracts. For example, we could implement automatic notifications for buyers and sellers upon successful transactions, trigger dispatch actions based on predefined conditions, and automate inventory management tasks.

*Advanced Tracking Features:*

Item tracking functionality can be further enhanced by incorporating real-time tracking capabilities and interactive visualizations. This could involve integrating GPS data or RFID technology to provide accurate location tracking and enable users to visualize the movement of items along the supply chain.

*User Authentication and Authorization:*

Implementation of robust user authentication and authorization mechanisms to ensure secure access to the application is another improvement that can be done in this application. This could include features such as user registration, login/logout functionality, and role-based access control to manage user permissions effectively.

*Analytics and Reporting:*

Introduction of analytics and reporting features to provide users with insights into supply chain performance and trends. This could include generating reports on transaction history, sales trends, inventory levels, and supply chain efficiency metrics, enabling users to make data-driven decisions.

*Security Analysis and Assurance:*

The application must undergo a comprehensive security analysis conducted by specialists to ensure the application's security is assured.

*Mobile Compatibility:*

Optimization of application for mobile devices to cater to users who prefer accessing the platform on smartphones and tablets. This could involve responsive design techniques and mobile app development to provide a seamless experience across different devices and platforms.

*Documentation and Support:*

Comprehensive documentation and support resources could be explored to assist users in navigating the application and understanding its features. This could include user guides, FAQs, video tutorials, and dedicated support channels to address user inquiries and issues promptly.

*Community Engagement:*

Possibility to foster a community around the application by implementing features such as discussion forums, user feedback mechanisms, complaint procedures and social sharing options. Encouraging user engagement and feedback can help drive adoption, improve user satisfaction, and foster a sense of belonging within the supply chain community.

# Conclusion

In conclusion, de-centra application represents a few significant possibilities in revolutionizing supply chain management through the integration of blockchain technology and smart contracts. In today's globalized marketplace, where efficiency and transparency are paramount, this application offers a compelling solution to address key challenges faced by businesses across industries.

The application idea raised from recognizing the inefficiencies and lack of transparency in traditional supply chain systems, which often lead to risks such as counterfeit products, ethical sourcing concerns, and supply chain disruptions. By leveraging blockchain technology, the application introduces transparency, traceability, and efficiency into supply chain processes, ultimately enhancing trust among participants and mitigating these risks. Through the utilization of smart contracts, the application automates and enforces contractual agreements, streamlining transactions and reducing administrative overhead.

Our functional demo application ‘de-centra’ showcases the potential of blockchain technology in revolutionizing supply chain management. Moving forward, there are several areas for improvement and expansion in the application. Enhancements such as an enhanced user interface, additional item attributes, integration with payment gateways and other wallets, smart contract automation, and advanced tracking features can further elevate the application's capabilities and user experience. Additionally, improvements in user authentication and authorization, analytics and reporting, mobile compatibility, documentation, support, and community engagement can contribute to the application's success and adoption.

Overall, de-centra serves as a testament to the transformative power of blockchain technology in supply chain management. By addressing key challenges and continually iterating on its functionalities, the application holds the potential to revolutionize supply chain processes, driving efficiency, transparency, and sustainability across industries worldwide.

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