

BLOCKCHAIN TECHNOLOGY

Unit V — Real-World Blockchain Applications & AI Integration

Topics Covered in this Unit

Data Provenance & Integrity: Immutable Audit Trails, Timestamping & Digital Document Notarization
Decentralized Data Marketplaces: Secure Data Monetization, Ocean Protocol & Privacy Preservation
Healthcare Applications: Electronic Health Records (EHR Interoperability) & Drug Traceability
Supply Chain Transparency: Anti-Counterfeiting, Farm-to-Fork Provenance & IoT Smart Contract Escrows
Financial Services & DeFi: Automated Market Makers (AMM $x*y=k$), Lending Protocols & Stablecoins
Self-Sovereign Identity (SSI): W3C Decentralized Identifiers (DIDs) & Verifiable Credentials (VCs)
Blockchain Voting Systems: Cryptographically Verifiable E-Voting & Coercion-Resistant Balloting
NFTs & Digital Asset Ownership: ERC-721/1155 Tokenization, Royalties & Metaverse Virtual Assets
Blockchain + AI/ML Integration: Decentralized Federated Learning, Autonomous AI Wallets & Deepfake Defense
High-Yield University Exam Question Bank with Detailed Model Answers & Unit Summary

*Compiled in a structured, easy-to-understand, textbook style format
Specially curated for B.Tech / B.E. / BCA / MCA / B.Sc Computer Science & IT Students*

COURSE SYLLABUS & MAPPING

[UNIT V SYLLABUS — PRESCRIBED UNIVERSITY CURRICULUM]

This section contains the official syllabus for Unit V. Verify with your university curriculum mapping.

Unit V Syllabus Breakdown:

Unit V - Blockchain Applications: Blockchain For Data Provenance and Integrity, Decentralized Data Marketplaces, Blockchain In Healthcare (Medical Records, Drug Traceability), Supply Chain Transparency And Tracking, Financial Services And Defi, Identity Management Systems, Voting Systems, NFTs And Digital Assets, Integration of Blockchain with AI/ML Models.

- Course Code: _____
- Semester / Year: _____



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5.1 Data Provenance, Integrity & Data Marketplaces

Definition: Data Provenance in Blockchain

Data Provenance refers to the complete, immutable historical audit trail of the origin, custody changes, transformations, and current state of a digital asset or data record cryptographically anchored on-chain.

1. Immutable Data Integrity & Document Notarization

- **Mechanism:** Instead of storing massive raw documents on-chain, the document's SHA-256 cryptographic digest is committed into a blockchain transaction. This establishes mathematical Proof of Existence, Proof of Authenticity, and exact chronological timestamping without exposing private contents (e.g., OpenTimestamps).

2. Decentralized Data Marketplaces (Ocean Protocol)

Traditional centralized data brokers monopolize consumer data. Decentralized data marketplaces allow data owners (individuals, IoT sensor networks) to publish, tokenize (ERC-20 datatokens), and monetize private datasets:

- **Compute-to-Data:** Allows third-party AI algorithms to train directly on private enterprise datasets without the raw data ever leaving the owner's firewall, preserving 100% data confidentiality while generating revenue.

5.2 Blockchain in Healthcare & Supply Chain Tracking

1. Healthcare: Electronic Health Records (EHR) & Drug Traceability

- **Patient-Centric Electronic Health Records (MedRec):** Solves the siloed medical record interoperability problem. Patients hold private keys controlling granular smart contract permissions, granting temporary view access to doctors/hospitals while maintaining an immutable audit log of all access events.
- **Pharmaceutical Anti-Counterfeiting:** According to WHO, counterfeit pharmaceuticals cause hundreds of thousands of deaths annually. Blockchain serializes every medicine batch with unique 2D cryptographic barcodes at manufacturing, tracking cold-chain IoT temperature logs and custodian handoffs until reaching the pharmacy patient.

2. Supply Chain Transparency & Asset Tracking

Supply Chain Problem	Traditional Centralized Logistics	Blockchain-Enabled Supply Chain Solution
Counterfeit Goods & Fraud	Paper invoices and easily faked centralized ERP records.	Immutable physical-to-digital pairing via tamper-proof NFC/RFID chips and on-chain hashes.
Lack of Origin Transparency	Opaque supplier sourcing; greenwashing and ethical violations.	Granular Provenance (e.g., Everledger tracking conflict-free diamonds from mine to retail; Farm-to-Fork food safety).
Settlement & Customs Delays	30–90 day payment cycles; manual letters of credit.	Automated Smart Contract Escrows: IoT sensors trigger instant payment releases upon GPS port arrival.

5.3 Decentralized Finance (DeFi) & Financial Primitives

Definition: Decentralized Finance (DeFi)

Decentralized Finance (DeFi) is an autonomous, open, permissionless financial ecosystem built on public smart contract blockchains (Ethereum, Solana) that replicates and reimagines traditional banking instruments (lending, borrowing, trading, derivatives) without central intermediaries.

Core DeFi Primitives & Protocols

- **1. Automated Market Makers (AMM - Uniswap):** Replaces traditional order books with liquidity pools governed by the Constant Product Invariant Formula: $x * y = k$ (where x is token A reserve, y is token B reserve, and k is a fixed constant). Token prices adjust dynamically based on pool ratios.
- **2. Lending & Borrowing Protocols (Aave, Compound):** Over-collateralized algorithmic lending pools. Users deposit collateral to earn interest or borrow against assets with automated liquidation triggers if collateralization ratios drop below safety thresholds.
- **3. Flash Loans:** Uncollateralized loans that must be borrowed, utilized (e.g., for cross-DEX arbitrage), and completely repaid within the exact same atomic blockchain transaction block! If repayment fails, the entire transaction reverts as if it never happened.
- **4. Stablecoins:** Cryptocurrencies pegged to fiat currencies (\$1 USD): Fiat-Backed (USDT, USDC), Crypto-Collateralized (DAI / MakerDAO over-collateralized by ETH), and Algorithmic Stablecoins.

5.4 Self-Sovereign Identity, Voting & NFTs

1. Self-Sovereign Identity (SSI) & W3C DIDs

Traditional identity relies on centralized silos (Google/Facebook login, Equifax) prone to massive data breaches. Self-Sovereign Identity (SSI) gives users complete cryptographic ownership over their digital identities:

- **Decentralized Identifier (DID):** A globally unique, cryptographically verifiable URI (e.g., did:ethr:0x123...) independent of any centralized registry.
- **Verifiable Credentials (VC):** Tamper-evident digital attestations issued by authorities (universities, governments) stored in the user's local cryptowallet. Users prove claims using Zero-Knowledge Proofs (e.g., proving age > 21 without revealing exact birth date!).

2. Cryptographic Blockchain Voting Systems

- **Core Requirements:** Voter anonymity, coercion-resistance, double-voting prevention, and end-to-end mathematical auditability. Uses blind signatures and Zero-Knowledge Proofs (ZKP) to ensure only eligible voters cast ballots while keeping individual choices 100% private.

3. Non-Fungible Tokens (NFTs) & Metaverse Digital Assets

- **Token Standards:** ERC-721 (unique single items) and ERC-1155 (semi-fungible multi-tokens for gaming economies). Smart contracts program perpetual secondary market creator royalties (e.g., 5% to original artist on every resale).

5.5 Integration of Blockchain with Artificial Intelligence (AI)

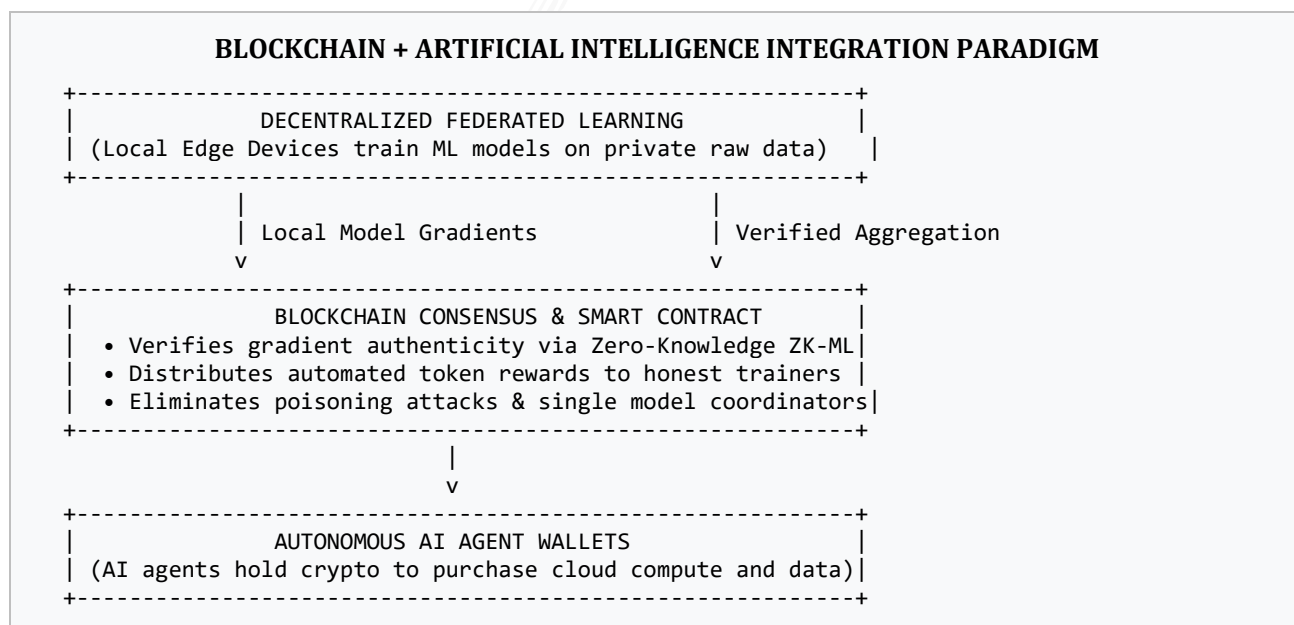


Figure: Synergistic integration of decentralized consensus, privacy-preserving AI and autonomous execution

Core Integration Synergies: Blockchain + AI

- **1. Decentralized Federated Learning:** Edge devices train machine learning models locally on private data. Model gradients are verified on-chain via smart contracts (ZK-ML), preventing data poisoning attacks while preserving consumer privacy.
- **2. Autonomous AI Agent Wallets:** Autonomous AI software agents equipped with crypto wallets (MetaMask / smart accounts) can independently pay for cloud compute (Render/Akash) and purchase API datasets without human bank account approval.
- **3. Combating Deepfakes & Synthetic Media:** Camera hardware cryptographically signs raw captured footage directly at the sensor level, embedding a SHA-256 hash into the blockchain to prove media provenance and authenticity against generative AI deepfakes.

5.6 High-Yield University Exam Question Bank

Part A: Short Answer Questions (2 to 5 Marks)

Q1. Explain the Constant Product Formula in Automated Market Makers (AMM). [3-4 Marks]

- **Answer:** In AMMs like Uniswap, liquidity pools maintain the invariant $x * y = k$, where x and y represent the reserve token amounts and k is constant. When a trader buys token X , reserve x decreases, causing reserve y to increase, naturally adjusting the price without order books.

Q2. How does blockchain prevent counterfeit drugs in healthcare supply chains? [3 Marks]

- **Answer:** Manufacturers assign unique cryptographic serial hashes to every medicine batch on-chain. Each supply chain handoff (distributor, cold-chain transport, pharmacy) is digitally signed on the ledger, allowing patients to verify authenticity via mobile QR scan.

Q3. What is Self-Sovereign Identity (SSI) and how do DIDs work? [4 Marks]

- **Answer:** SSI gives individuals complete ownership of their digital identity without relying on centralized identity providers. Decentralized Identifiers (DIDs) are globally unique, cryptographically verifiable IDs stored in digital wallets with Zero-Knowledge Verifiable Credentials.

Part B: Long Answer Questions (10 to 15 Marks Outline Guides)

- **Q4. Explain Blockchain Applications in Healthcare (EHR interoperability, patient consent, and pharmaceutical drug supply chain traceability). [12 Marks]**
- **Q5. Discuss Decentralized Finance (DeFi) primitives: Automated Market Makers (Uniswap), Lending Pools (Aave), Flash Loans, and Collateralized Stablecoins. [12 Marks]**
- **Q6. Detail how Blockchain is integrated with Artificial Intelligence (AI) for Decentralized Federated Learning, Autonomous Agent Wallets, and Deepfake authentication. [12 Marks]**
- **Q7. Explain Blockchain Voting Systems, electronic voting requirements, coercion resistance, and Zero-Knowledge verification. [10 Marks]**

5.7 Unit Summary & Key Takeaways

- Blockchain provides immutable data provenance, tamper-evident document notarization, and decentralized data marketplace monetization (Ocean Protocol).
- Healthcare utilizes blockchain for patient-controlled EHR interoperability and cold-chain anti-counterfeiting drug tracking.
- Supply chains benefit from end-to-end physical-to-digital tracking and automated smart contract payment releases.
- DeFi replaces centralized financial intermediaries using AMMs ($x * y = k$), lending pools, flash loans, and stablecoins.
- Self-Sovereign Identity (SSI) and W3C DIDs provide privacy-preserving cryptographic identity credentials.
- Blockchain + AI integration powers decentralized federated learning, autonomous AI agent wallets, and cryptographic deepfake provenance verification.

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