Subject Name Solutions

4361603 – Winter 2024

Semester 1 Study Material

Detailed Solutions and Explanations

Question 1(a) [3 marks]

Short Note on: Distributed Ledger

Solution

Table 1: Distributed Ledger Features

Feature	Description
Definition	Database spread across multiple computers
Storage	Data stored in multiple locations
Control	No single authority owns it
Updates	All copies updated simultaneously

- **Decentralized**: No central server needed
- **Transparent**: All participants can see transactions
- **Secure**: Uses cryptography for protection

Mnemonic

"Data Stored Transparently Securely" (DSTS)

Question 1(b) [4 marks]

Describe the applications of Blockchain.

Solution

Table 2: Blockchain Applications

Application	Use Case	Benefit
Cryptocurrency	Digital money like Bitcoin	Secure payments
Supply Chain	Track products from source	Prevent fake goods
Healthcare	Store medical records	Data security
Voting	Electronic voting system	Transparent elections
Real Estate	Property records	Fraud prevention

- **Finance**: Faster cross-border payments
- **Identity**: Digital ID verification
- **Smart Contracts**: Automated agreements

Mnemonic

"Money, Medicine, Voting, Property" (MMVP)

Question 1(c) [7 marks]

Explain Asymmetric Encryption Model with example.

Solution

Diagram: Asymmetric Encryption Process

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Sender] {-{-}{} B[Public Key]}
    B {-{-}{} C[Encrypt Message]}
    C {-{-}{} D[Encrypted Data]}
    D {-{-}{} E[Receiver]}
    E {-{-}{} F[Private Key]}
    F {-{-}{} G[Decrypt Message]}
    G {-{-}{} H[Original Message]}
{Highlighting}
{Shaded}
```

Table 3: Key Comparison

Key Type	Purpose	Sharing	Example
Public Key	Encryption	Shared openly	RSA Public Key
Private Key	Decryption	Kept secret	RSA Private Key

Example Process:

1. Alice wants to send message to Bob
2. Alice uses Bob's public key to encrypt
3. Only Bob's private key can decrypt
4. Bob receives and decrypts message

- **Security**: Even if public key is known, data stays safe
- **Authentication**: Proves sender identity
- **Non-repudiation**: Sender cannot deny sending

Mnemonic

"Public Encrypts, Private Decrypts" (PEPD)

Question 1(c OR) [7 marks]

Explain Consistency, Availability and Partition Tolerance (CAP) theorem in Blockchain.

Solution

Diagram: CAP Theorem Triangle

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[CAP Theorem]
    A {-{-}{} B[Consistency]}
    A {-{-}{} C[Availability]}
    A {-{-}{} D[Partition Tolerance]}

    B {-{-}{} E["All nodes see same data"]}
```

```
    C {-{-}{} F["System always responds"]}
    D {-{-}{} G["Works despite network failures"]}
{Highlighting}
{Shaded}
```

Table 4: CAP Properties

Property	Definition	Blockchain Focus
Consistency	All nodes have same data	Medium priority
Availability	System always responds	High priority
Partition Tolerance	Works with network splits	High priority

Key Points:

- **Trade-off**: Can only guarantee 2 out of 3 properties
- **Blockchain Choice**: Usually prioritizes Availability + Partition Tolerance
- **Real Example**: Bitcoin chooses AP over C (eventual consistency)

Mnemonic

"Choose Any Two" (CAT)

Question 2(a) [3 marks]

Define: Public key, Private key, Digital Signature.

Solution

Table 5: Cryptographic Components

Component	Definition	Usage
Public Key	Encryption key shared openly	Encrypt data, verify signatures
Private Key	Secret key kept by owner	Decrypt data, create signatures
Digital Signature	Encrypted hash of message	Prove authenticity and integrity

Mnemonic

"Public Protects, Private Proves" (PPPP)

Question 2(b) [4 marks]

Explain Public blockchain with its advantage and disadvantage.

Solution

Table 6: Public Blockchain Analysis

Aspect	Details
Definition	Open network accessible to everyone
Examples	Bitcoin, Ethereum

Advantages:
- **Transparency**: All transactions visible
- **Decentralization**: No single control
- **Security**: Many nodes validate

Disadvantages:
- **Speed**: Slow transaction processing
- **Energy**: High power consumption
- **Scalability**: Limited transactions per second

Mnemonic

"Transparent but Slow" (TBS)

Question 2(c) [7 marks]

Describe Core components of Blockchain.

Solution

Diagram: Blockchain Structure

```
graph TB
    A[Block N{-1] {-}{-} B[Block N]}
    B {-{-} C[Block N+1]}

    B {-{-} D[Block Header]}
    B {-{-} E[Transaction Data]}

    D {-{-} F[Previous Hash]}
    D {-{-} G[Merkle Root]}
    D {-{-} H[Timestamp]}
    D {-{-} I[Nonce]}
```

Table 7: Core Components

Component	Function	Importance
Block	Container for transactions	Data storage
Hash	Unique identifier	Security
Merkle Tree	Transaction summary	Verification
Nonce	Mining number	Proof of work
Timestamp	Time record	Chronological order
Previous Hash	Links to previous block	Chain integrity

- **Immutability**: Cannot change past records
- **Transparency**: All data visible
- **Consensus**: Network agrees on validity

Mnemonic

"Blocks Hash Merkle Nonce Time Previous" (BHMNTP)

Question 2(a OR) [3 marks]

Short Note on: SideChain

Solution

Table 8: SideChain Features

Feature	Description
Definition	Separate blockchain connected to main chain
Purpose	Extend main blockchain functionality
Connection	Two-way peg mechanism

- **Scalability**: Reduces main chain load
- **Flexibility**: Custom features possible
- **Security**: Inherits main chain security

Mnemonic

"Separate Side Scales" (SSS)

Question 2(b OR) [4 marks]

Explain Private blockchain with its advantage and disadvantage.

Solution

Table 9: Private Blockchain Analysis

Aspect	Details
Definition	Restricted network with controlled access
Control	Single organization manages

Advantages:
- **Speed**: Faster transactions
- **Privacy**: Controlled data access
- **Efficiency**: Lower energy consumption
- **Compliance**: Meets regulatory requirements

Disadvantages:
- **Centralization**: Single point of control
- **Trust**: Relies on controlling organization
- **Limited**: Fewer participants

Mnemonic

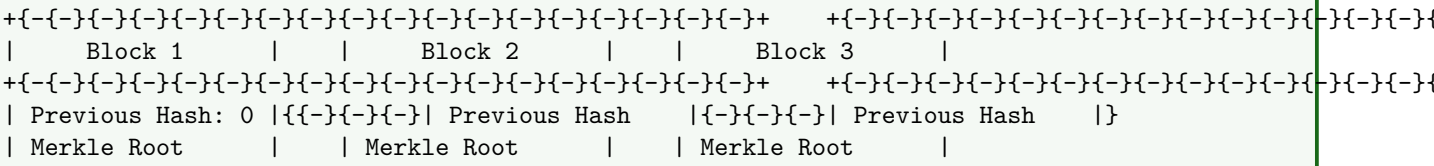
"Fast Private Controlled" (FPC)

Question 2(c OR) [7 marks]

Explain Data structure of Blockchain.

Solution

Diagram: Blockchain Data Structure



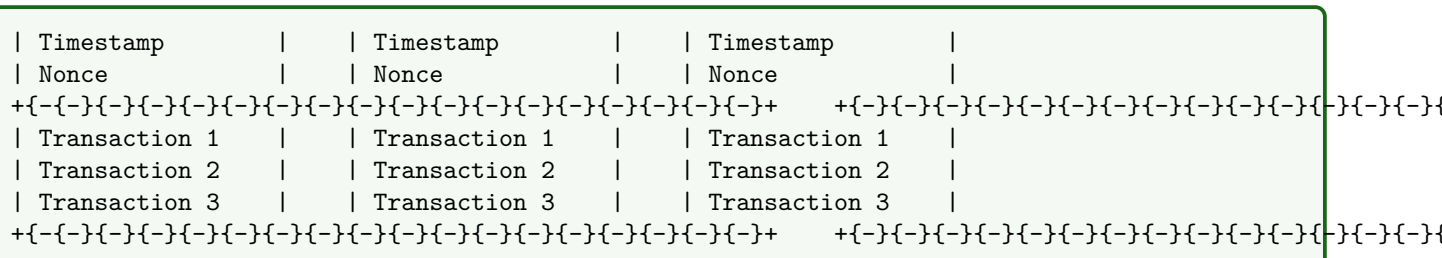


Table 10: Data Structure Elements

Element	Purpose	Size
Block Header	Contains metadata	Fixed size
Transaction List	Actual data	Variable size
Hash Pointer	Links blocks	256 bits
Merkle Tree	Transaction summary	Logarithmic

Key Features:

- **Linear Structure**: Blocks linked in sequence
- **Hash Linking**: Each block references previous
- **Merkle Trees**: Efficient transaction verification
- **Immutable**: Cannot modify without detection

Mnemonic

"Linear Hash Merkle Immutable" (LHMI)

Question 3(a) [3 marks]

Short Note on: Consensus Mechanism in Blockchain.

Solution

Table 11: Consensus Mechanism

Aspect	Description
Purpose	Agree on network state
Need	Prevent double spending
Types	PoW, PoS, DPoS

- **Agreement**: All nodes must agree
- **Decentralization**: No central authority
- **Security**: Prevents malicious activities

Mnemonic

"Agreement Prevents Security" (APS)

Question 3(b) [4 marks]

Compare Hard Fork and Soft Fork in Blockchain.

Solution

Table 12: Fork Comparison

Feature	Hard Fork	Soft Fork
Compatibility	Not backward compatible	Backward compatible
Rules	Creates new rules	Tightens existing rules
Upgrade	All nodes must upgrade	Optional upgrade
Result	Two separate chains	Single chain continues
Example	Ethereum to Ethereum Classic	Bitcoin SegWit

Key Differences:
- **Hard Fork**: Permanent split in blockchain
- **Soft Fork**: Temporary restriction that becomes permanent

Mnemonic

"Hard Splits, Soft Restricts" (HSSR)

Question 3(c) [7 marks]

What is Proof of Work? How does it work? Explain with example.

Solution

Diagram: Proof of Work Process

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[New Transactions] {-{-}{} B[Create Block]}
    B {-{-}{} C[Calculate Hash]}
    C {-{-}{} D\{Hash starts with zeros?\}}
    D {-{-}{}|No| E[Change Nonce]}
    E {-{-}{} C}
    D {-{-}{}|Yes| F[Block Valid]}
    F {-{-}{} G[Add to Blockchain]}
    G {-{-}{} H[Miner Rewarded]}
{Highlighting}
{Shaded}
```

Table 13: PoW Components

Component	Function	Example
Hash Function	Creates unique fingerprint	SHA-256
Nonce	Random number to change hash	12345
Difficulty	Required number of leading zeros	4 zeros
Mining	Computing process	Bitcoin mining

Working Process:
1. Collect pending transactions
2. Create block with transactions
3. Try different nonce values
4. Calculate hash repeatedly
5. Find hash with required zeros
6. Broadcast valid block to network

Bitcoin Example:
- **Target**: Hash must start with specific zeros
- **Time**: ~10 minutes per block
- **Reward**: 6.25 BTC (as of 2024)

Mnemonic

"Try Calculate Until Zero" (TCUZ)

Question 3(a OR) [3 marks]

Short Note on: Block Rewards in Blockchain.

Solution

Table 14: Block Rewards

Feature	Description
Purpose	Incentivize miners
Components	Block reward + transaction fees
Bitcoin	Started at 50 BTC, halves every 4 years

- **Motivation**: Encourages network participation
- **Halving**: Reduces inflation over time
- **Fees**: Additional income for miners

Mnemonic

"Miners Motivated Money" (MMM)

Question 3(b OR) [4 marks]

What is 51% attack and how does it work?

Solution

Table 15: 51% Attack Analysis

Aspect	Details
Definition	Controlling majority mining power
Threshold	More than 50% network hash rate
Capability	Can reverse transactions
Limitation	Cannot steal others' coins

How it Works:

1. Attacker gains majority mining power
2. Creates private blockchain fork
3. Mines faster than honest network
4. Releases longer chain to network
5. Network accepts longer chain as valid

Consequences:

- **Double Spending**: Spend same coins twice
- **Transaction Reversal**: Cancel confirmed transactions
- **Network Trust**: Damages blockchain credibility

Mnemonic

"Majority Controls Chain" (MCC)

Question 3(c OR) [7 marks]

What is Proof of Stake? How does it work? Explain with example.

Solution

Diagram: Proof of Stake Process

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Validators Stake Coins] {-{-}{} B[Random Selection]}
    B {-{-}{} C[Selected Validator]}
    C {-{-}{} D[Propose New Block]}
    D {-{-}{} E[Other Validators Vote]}
    E {-{-}{} F\{Majority Agrees?\}}
    F {-{-}{}|Yes| G[Block Added]}
    F {-{-}{}|No| H[Block Rejected]}
    G {-{-}{} I[Validator Rewarded]}
    H {-{-}{} J[Validator Penalized]}
{Highlighting}
{Shaded}
```

Table 16: PoS vs PoW

Feature	Proof of Stake	Proof of Work
Energy	Low consumption	High consumption
Selection	Stake-based	Computing power
Hardware	Regular computer	Specialized miners
Speed	Faster	Slower

Working Process:

1. Validators lock coins as stake
2. Algorithm selects validator randomly
3. Selection probability based on stake size
4. Chosen validator proposes block
5. Other validators verify and vote
6. Rewards distributed to honest validators

Ethereum Example:

- **Minimum Stake**: 32 ETH required
- **Penalties**: Slashing for malicious behavior
- **Rewards**: Annual percentage yield

Key Benefits:

- **Energy Efficient**: No intensive mining
- **Economic Security**: Validators lose stake if dishonest
- **Scalability**: Faster transaction processing

Mnemonic

"Stake Select Validate Reward" (SSVR)

Question 4(a) [3 marks]

Describe Byzantine Fault Tolerance.

Solution

Table 17: Byzantine Fault Tolerance

Aspect	Description
Problem	Some nodes may act maliciously
Tolerance	System works despite faulty nodes
Requirement	Less than 1/3 nodes can be faulty

- **Consensus**: Honest nodes must agree
- **Resilience**: Network survives attacks
- **Application**: Used in blockchain consensus

Mnemonic

"Faulty Nodes Tolerated" (FNT)

Question 4(b) [4 marks]

How smart contract works in blockchain?

Solution

Diagram: Smart Contract Execution

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Contract Created] {-{-}{} B[Deployed on Blockchain]}
    B {-{-}{} C[Conditions Met]}
    C {-{-}{} D[Automatic Execution]}
    D {-{-}{} E[Results Recorded]}
{Highlighting}
{Shaded}
```

Working Process:

- **Creation**: Developer writes contract code
- **Deployment**: Contract stored on blockchain
- **Trigger**: External event activates contract
- **Execution**: Code runs automatically
- **Immutable**: Cannot be changed after deployment

Key Features:

- **Self-executing**: No intermediary needed
- **Transparent**: Code visible to all
- **Cost-effective**: Reduces transaction costs

Mnemonic

"Code Executes Automatically" (CEA)

Question 4(c) [7 marks]

What is SHA-256 and what is the use of SHA-256 in Blockchain.

Solution

Table 18: SHA-256 Properties

Property	Description
Full Name	Secure Hash Algorithm 256-bit
Output	Always 256 bits (64 hex characters)
Input	Any size data
Nature	One-way function

Diagram: SHA-256 in Blockchain

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Block Data] {-{-}{} B[SHA{-}256 Hash]}
    B {-{-}{} C[Block Hash]}
    C {-{-}{} D[Previous Hash Reference]}
    D {-{-}{} E[Chain Integrity]}
{Highlighting}
{Shaded}
```

Uses in Blockchain:

1. **Block Hashing**: Create unique block identifier
2. **Merkle Trees**: Summarize all transactions
3. **Proof of Work**: Mining difficulty target
4. **Digital Signatures**: Secure transaction signing
5. **Wallet Addresses**: Generate Bitcoin addresses

Key Properties:

- **Deterministic**: Same input = same output
- **Avalanche Effect**: Small change = completely different hash
- **Irreversible**: Cannot find input from output
- **Collision Resistant**: Two inputs rarely same output

Example:

- Input: "Hello World"
- SHA-256: a591a6d40bf420404a011733cfb7b190d62c65bf0bcda32b57b277d9ad9f146e

Mnemonic

"Hash Identifies Secures Proves" (HISP)

Question 4(a OR) [3 marks]

Explain Bitcoin and eventual consistency.

Solution

Table 19: Bitcoin Consistency

Concept	Description
Eventual Consistency	All nodes eventually agree
Temporary Forks	Multiple valid chains exist
Resolution	Longest chain wins

- **Time Delay**: Network propagation takes time
- **Confirmation**: More blocks = higher certainty
- **Finality**: Becomes practically irreversible

Mnemonic

"Eventually Everyone Agrees" (EEA)

Question 4(b OR) [4 marks]

Discuss types of smart contract in blockchain.

Solution

Table 20: Smart Contract Types

Type	Function	Example
Legal Contract	Legally binding agreements	Real estate transfer
Application Logic	Decentralized app functions	Token exchange
Decentralized Autonomous	Self-governing organizations	DAO voting
Multi-signature	Require multiple approvals	Escrow services

Key Categories:

- **Financial**: Payment and lending contracts
- **Insurance**: Automated claim processing
- **Supply Chain**: Track product authenticity
- **Gaming**: In-game asset management

Mnemonic

"Legal Logic Autonomous Multi" (LLAM)

Question 4(c OR) [7 marks]

Define Merkle Tree and explain how it works in blockchain.

Solution

Diagram: Merkle Tree Structure

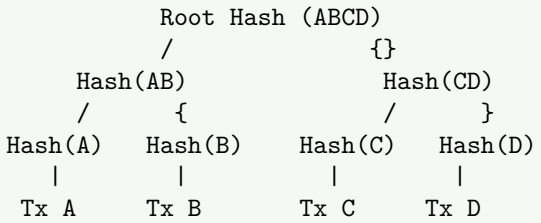


Table 21: Merkle Tree Benefits

Benefit	Description
Efficiency	Verify transactions without downloading all data
Security	Any change detected immediately
Scalability	Logarithmic verification time
Storage	Compact representation

Working Process:

1. **Hash Transactions**: Each transaction gets hash
2. **Pair Hashing**: Combine adjacent hashes
3. **Repeat Process**: Continue until single root hash
4. **Root Storage**: Store only root in block header
5. **Verification**: Prove transaction with path to root

Blockchain Usage:

- **Block Header**: Contains Merkle root
- **SPV Verification**: Light clients verify without full blockchain
- **Tamper Detection**: Any change breaks tree structure
- **Efficient Sync**: Download only necessary parts

Bitcoin Example:

- Block contains thousands of transactions
- Only 32-byte Merkle root stored in header
- Can verify any transaction with ~10 hashes

Mnemonic

"Tree Organizes Verifies Efficiently" (TOVE)

Question 5(a) [3 marks]

Short Note on: Bitcoin Scripting

Solution

Table 22: Bitcoin Scripting

Feature	Description
Language	Stack-based programming language
Purpose	Define spending conditions
Execution	Runs when coins are spent

- **Simple**: Basic operations only
- **Secure**: Limited functionality prevents abuse
- **Flexible**: Various transaction types possible

Mnemonic

"Stack Defines Spending" (SDS)

Question 5(b) [4 marks]

Explain Decentralized Applications (dApps) in Blockchain and how does it work?

Solution

Table 23: dApp Components

Component	Function
Frontend	User interface
Backend	Smart contracts on blockchain
Storage	Decentralized storage systems
Network	Peer-to-peer communication

Working Process:

1. User interacts with web interface
2. Frontend connects to blockchain
3. Smart contracts execute business logic
4. Results stored on blockchain
5. Updates reflect across network

Key Features:

- **No Central Server**: Runs on distributed network
- **Open Source**: Code publicly available
- **Autonomous**: Operates without company control

Mnemonic

"Decentralized Apps Run Everywhere" (DARE)

Question 5(c) [7 marks]

Explain Hyperledger with its advantages and disadvantages.

Solution

Table 24: Hyperledger Overview

Aspect	Description
Type	Private/Consortium blockchain platform
Developer	Linux Foundation
Target	Enterprise applications
Consensus	Pluggable consensus mechanisms

Diagram: Hyperledger Architecture

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Application Layer] {-{-}{} B[Hyperledger Fabric]}
    B {-{-}{} C[Chaincode/Smart Contracts]}
    B {-{-}{} D[Consensus Layer]}
    B {-{-}{} E[Membership Services]}
    D {-{-}{} F[Ordering Service]}
    E {-{-}{} G[Certificate Authority]}
{Highlighting}
{Shaded}
```

Advantages:

- **Performance**: High transaction throughput
- **Privacy**: Confidential transactions
- **Modular**: Pluggable components
- **Enterprise Ready**: Production-grade features
- **Governance**: Controlled network access
- **Compliance**: Meets regulatory requirements

Disadvantages:

- **Centralization**: Not fully decentralized
- **Complexity**: Difficult to set up
- **Vendor Lock-in**: Platform dependency
- **Limited Transparency**: Private network
- **Cost**: Expensive infrastructure

Use Cases:

- Supply chain management
- Trade finance
- Healthcare records
- Identity management

Mnemonic

"Private Performance Enterprise" (PPE)

Question 5(a OR) [3 marks]

Short Note on: Bitcoin Mining

Solution

Table 25: Bitcoin Mining

Aspect	Description
Purpose	Validate transactions and create blocks
Process	Solve cryptographic puzzles
Reward	BTC + transaction fees

- **Hardware**: Specialized ASIC miners
- **Energy**: High electricity consumption
- **Competition**: Global mining pools compete

Mnemonic

"Validate Solve Reward" (VSR)

Question 5(b OR) [4 marks]

Short Note on: Decentralized Autonomous Organization (DAO)

Solution

Table 26: DAO Features

Feature	Description
Governance	Community-driven decisions
Voting	Token-based voting rights
Automation	Smart contracts execute decisions
Transparency	All activities on blockchain

Key Characteristics:

- **No Central Authority**: Community controlled
- **Token Ownership**: Voting power based on tokens
- **Proposal System**: Members suggest changes
- **Automatic Execution**: Approved proposals execute automatically

Examples:

- MakerDAO (DeFi protocol)
- Uniswap (Decentralized exchange)
- Aragon (DAO infrastructure)

Challenges:

- **Security Risks**: Smart contract vulnerabilities
- **Governance Issues**: Low voter participation
- **Legal Status**: Regulatory uncertainty

Mnemonic

"Community Votes Automatically" (CVA)

Question 5(c OR) [7 marks]

Explain ERC-20 with its advantages and disadvantages

Solution

Table 27: ERC-20 Standard

Aspect	Description
Full Name	Ethereum Request for Comments 20
Type	Token standard on Ethereum
Functions	Standardized token operations
Compatibility	Works with all Ethereum wallets

Diagram: ERC-20 Token Flow

Mermaid Diagram (Code)

```
{Shaded}
{Highlighting}[]
graph LR
    A[Token Contract] {-{-}{} B[Transfer Function]}
    B {-{-}{} C[Update Balances]}
    C {-{-}{} D[Emit Event]}
    D {-{-}{} E[Wallet Updates]}
{Highlighting}
{Shaded}
```

Required Functions:

Function	Purpose
totalSupply()	Return total token supply
balanceOf()	Check account balance
transfer()	Send tokens to address
approve()	Allow spending on behalf
transferFrom()	Transfer approved tokens
allowance()	Check approved amount

Advantages:

- **Standardization**: Uniform interface for all tokens
- **Interoperability**: Works with any Ethereum wallet/exchange
- **Easy Integration**: Simple for developers to implement
- **Liquidity**: Can trade on decentralized exchanges
- **Smart Contract**: Programmable money features
- **Global Access**: Available worldwide 24/7

Disadvantages:

- **Gas Fees**: Ethereum transaction costs
- **Scalability**: Network congestion issues
- **Flexibility**: Limited compared to newer standards
- **Security**: Smart contract vulnerabilities
- **Complexity**: Technical knowledge required
- **Regulatory**: Unclear legal status

Popular ERC-20 Tokens:

- USDT (Tether)
- LINK (Chainlink)
- UNI (Uniswap)

Mnemonic

"Standard Tokens Trade Everywhere" (STTE)