L19: Token Lifecycle Management

Module B: Ethereum & Smart Contracts

Blockchain & Cryptocurrency Course

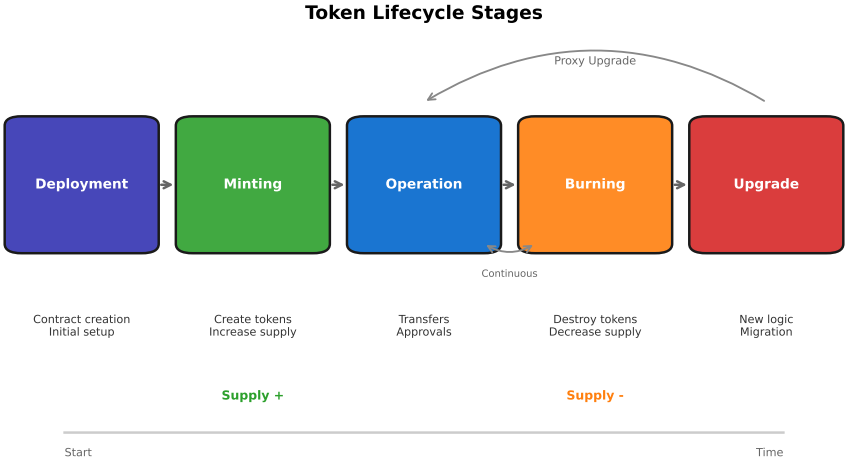
December 2025

Learning Objectives

By the end of this lesson, you will be able to:

- Implement various minting strategies (owner, public, allowlist, merkle tree)
- Design burning mechanisms for deflationary tokenomics
- Use Pausable pattern for emergency circuit breakers
- Apply access control patterns (Ownable, AccessControl, multi-sig)
- Understand upgradeability patterns (Transparent Proxy, UUPS)
- Implement time-locked operations and governance mechanisms

Token Lifecycle Overview



Tokens progress through deployment, minting, operation, burning, and potential upgrades

Token Lifecycle Stages

Complete lifecycle of a token contract:

1. **Deployment:** Contract creation, owner/admin setup, initial distribution
2. **Minting:** Creating new tokens (increasing supply), controlled by governance or owner
3. **Operation:** Normal transfers, approvals, staking, may include pause capability
4. **Burning:** Destroying tokens (decreasing supply), voluntary or forced mechanisms
5. **Upgrade/Migration:** Proxy upgrades or token swaps, governance-controlled

Minting Strategy 1: Owner-Controlled

Simple admin-based minting:

```
import "@openzeppelin/contracts/token/ERC20/ERC20.sol";
import "@openzeppelin/contracts/access/Ownable.sol";

contract OwnerMintToken is ERC20, Ownable {
    constructor() ERC20("Owner Mint Token", "OMT") {}

    function mint(address to, uint256 amount) public onlyOwner {
        _mint(to, amount);
    }
}
```

Advantages: Simple, flexible timing, useful for airdrops and team allocation
Disadvantages: Centralized control, risk of unlimited inflation, regulatory concerns

Minting Strategy 2: Public Mint with Cap

Anyone can mint up to a maximum supply:

```
contract PublicMintToken is ERC20 {
    uint256 public constant MAX_SUPPLY = 1_000_000 * 10**18;
    uint256 public constant MINT_PRICE = 0.01 ether;
    uint256 public constant MAX_PER_TX = 10 * 10**18;

    function mint(uint256 amount) public payable {
        require(totalSupply() + amount <= MAX_SUPPLY, "Max supply exceeded");
        require(amount <= MAX_PER_TX, "Exceeds max per transaction");
        require(msg.value >= amount * MINT_PRICE / 10**18, "Insufficient payment");
        _mint(msg.sender, amount);
    }
}
```

Use Cases: NFT mints, fair launch tokens, crowdfunding

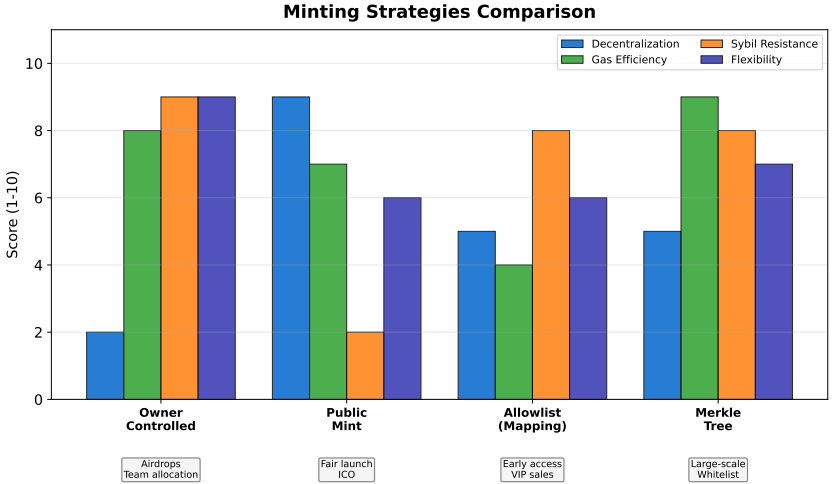
Minting Strategy 3: Merkle Tree Allowlist

Gas-efficient allowlist using Merkle proofs:

```
import "@openzeppelin/contracts/utils/cryptography/MerkleProof.sol";

contract MerkleMintToken is ERC20 {
    bytes32 public merkleRoot;
    mapping(address => bool) public hasClaimed;

    constructor(bytes32 _merkleRoot) ERC20("Merkle Token", "MTK") {
        merkleRoot = _merkleRoot;
    }

    function claim(uint256 amount, bytes32[] calldata merkleProof) public {
        require(!hasClaimed[msg.sender], "Already claimed");
        bytes32 leaf = keccak256(abi.encodePacked(msg.sender, amount));
        require(MerkleProof.verify(merkleProof, merkleRoot, leaf), "Invalid proof");
        hasClaimed[msg.sender] = true;
        _mint(msg.sender, amount);
    }
}
```

Advantage: Store single root hash (32 bytes) instead of entire allowlist

Minting Strategies Comparison



Merkle tree offers best gas efficiency for large allowlists

Burning Mechanisms

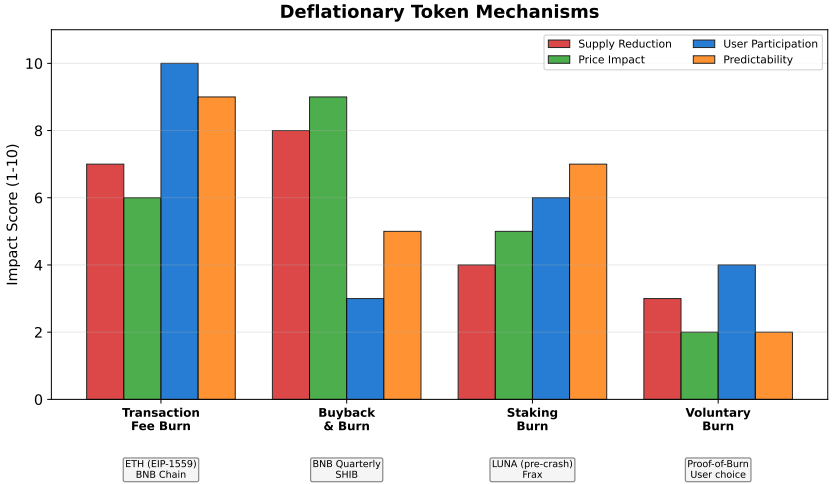
Destroying tokens to reduce supply:

```
import "@openzeppelin/contracts/token/ERC20/extensions/ERC20Burnable.sol";

contract BurnableToken is ERC20Burnable {
    constructor() ERC20("Burnable Token", "BURN") {
        _mint(msg.sender, 1_000_000 * 10**18);
    }
    // Inherited: burn(uint256 amount) - burns caller's tokens
    // Inherited: burnFrom(address account, uint256 amount) - burns with allowance
}
```

Burn Strategies:

- **Voluntary:** Users burn their own tokens (e.g., for utility)
- **Fee Burn:** Transaction fees burned automatically (EIP-1559 model)
- **Buyback & Burn:** Protocol buys tokens from market and burns them

Deflationary Token Mechanisms



Transaction fee burns are most predictable; buyback has highest price impact

Access Control: Ownable Pattern

Single owner with full control:

```
import "@openzeppelin/contracts/access/Ownable.sol";

contract OwnedToken is ERC20, Ownable {
    constructor() ERC20("Owned Token", "OWN") {}

    function mint(address to, uint256 amount) public onlyOwner {
        _mint(to, amount);
    }

    function renounceOwnership() public override onlyOwner {
        // Irreversibly give up ownership (contract becomes unmanaged)
        super.renounceOwnership();
    }
}
```

Risk: Single point of failure (owner key compromise = full control loss)
Mitigation: Use multi-sig wallet as owner (Gnosis Safe)

Access Control: Multi-Signature Wallets

Require multiple approvals for critical operations:

Gnosis Safe Example:

- 3-of-5 multi-sig: Requires 3 out of 5 owners to approve transaction
- Prevents single key compromise
- Common setup: Deploy token with Gnosis Safe as owner

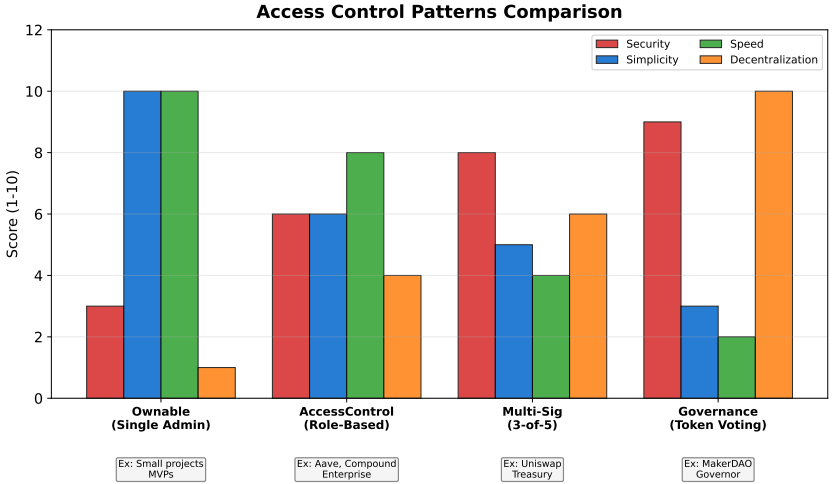
Workflow:

1. Owner 1 proposes transaction (e.g., `mint(alice, 1000)`)
2. Owners 2 and 3 approve transaction
3. Transaction executes automatically when threshold reached

Real-World Usage:

- Uniswap: 4-of-7 multi-sig controls protocol fees
- Compound: Timelock + multi-sig for governance execution

Access Control Patterns Comparison



Multi-sig balances security and speed; governance offers maximum decentralization

Upgradeability: Why and Risks

Motivation for upgradeable contracts:

- Fix critical bugs without redeploying
- Add new features (e.g., staking, governance)
- Comply with changing regulations

Fundamental Challenge:

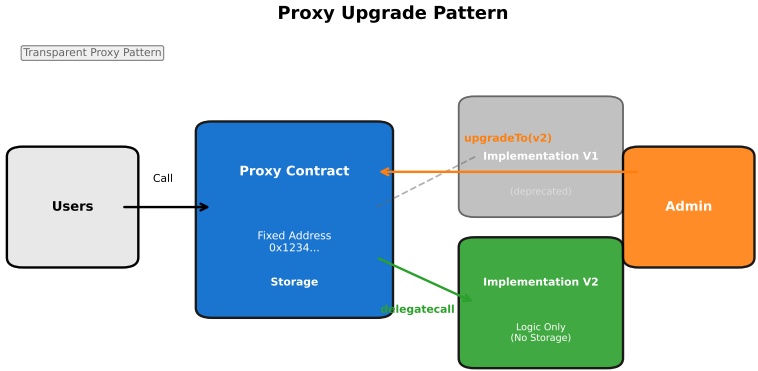
- Smart contracts are immutable after deployment
- Bytecode cannot be changed

Solution: Proxy Pattern

- **Proxy Contract:** Fixed address, users interact with this
- **Implementation Contract:** Contains logic, can be swapped
- Proxy uses `delegatecall` to execute implementation logic

Risks: Admin can rug pull, storage layout collisions, requires trust

Proxy Upgrade Pattern



Storage stays in proxy; only logic is upgraded via delegatecall

Upgradeability: Transparent Proxy

Separate admin and user interfaces:

```
// Proxy Contract (deployed once, never changes)
contract TransparentProxy {
    address public implementation;
    address public admin;

    function upgradeTo(address newImplementation) external {
        require(msg.sender == admin, "Not admin");
        implementation = newImplementation;
    }

    fallback() external payable {
        address impl = implementation;
        assembly {
            calldatacopy(0, 0, calldatasize())
            let result := delegatecall(gas(), impl, 0, calldatasize(), 0, 0)
            returndatacopy(0, 0, returndatasize())
            switch result
            case 0 { revert(0, returndatasize()) }
            default { return(0, returndatasize()) }
        }
    }
}
```

Key Takeaways

1. **Minting Strategies:** Owner-controlled (centralized), public mint (open), Merkle tree (gas-efficient allowlist)
2. **Burning:** Voluntary burn, fee burn, buyback and burn for deflationary tokenomics
3. **Pausable:** Emergency circuit breaker halts transfers during critical bugs
4. **Access Control:** Ownable (single admin), AccessControl (role-based), multi-sig (distributed trust)
5. **Upgradeability:** Transparent Proxy separates storage from logic, enabling upgrades
6. **Timelock:** Delay critical operations to allow community reaction and exit
7. **Governance:** Token-weighted voting enables decentralized control

Discussion Questions

1. What are the security tradeoffs between Merkle tree allowlists and simple mapping-based allowlists?
2. Should all tokens be pausable, or does this introduce too much centralization risk?
3. How can upgradeable contracts maintain credible neutrality when admins can change the code?
4. What is the optimal timelock delay for different types of governance actions?
5. How do deflationary tokenomics affect long-term protocol sustainability?

Next Lesson Preview: L20 - Lab: Token Analysis

Coming up next (hands-on lab):

- Analyzing USDC and DAI contracts on Etherscan
- Examining token holder distribution and centralization
- Tracking transaction patterns and whale movements
- Identifying upgrade events and governance actions
- Deploying your own ERC-20 token with custom features

Preparation:

- Review Etherscan contract reading interface
- Familiarize with USDC and DAI token pages
- Prepare Sepolia testnet ETH for deployment