Post-Quantum Transaction Signatures

PQTS Breakout Room — ZKNOX contributions

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Slides: github.com/ZKNoxHQ/Communications/pqts-breakout

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What We Have Today — Full Operational Suite with Dapp Integration

Precompile EIPs (deployed on testnet):

- EIP-8051: ML-DSA (Dilithium) precompile
- EIP-8052: FN-DSA (Falcon) precompile
- Ethereum-optimized variants (Keccak PRNG)

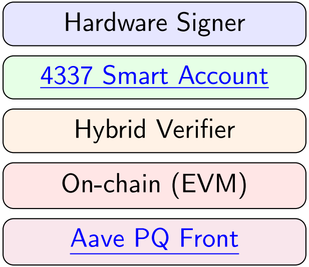
Signer implementations:

- ML-DSA on Ledger hardware wallet
- Falcon software signer
- PQ-BIP39 key derivation (zk PQ hatch friendly)

Hybrid & agile verifier (ERC-4337):

- ECDSA (k1/r1) + ML-DSA/FN-DSA
- ETH-optimized or NIST-native
- Modular, swappable verifiers

Full stack:



Hardware Signer

4337 Smart Account

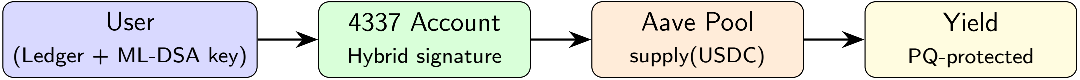
Hybrid Verifier

On-chain (EVM)

Aave PQ Front

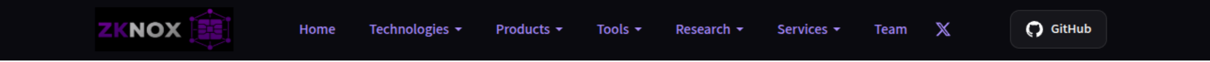
Protecting High-Value Use Cases **Today**

Key insight: We don't need precompiles to start protecting assets *now*.
Pure Solidity verification works — and at current gas prices, it's affordable.



Scheme	**Gas (Solidity)**	**Cost @0.55 gwei, ETH=$2322**
ML-DSA (NIST)	13.0M gas	$16.60
ML-DSA-ETH	8.3M gas	$10.60
Falcon (NIST)	4.1M gas	$5.24
Falcon-ETH	1.6M gas	**$2.04**

Use cases (no precompile needed): governance contracts, treasury management, DeFi yield positions (Aave, Compound), multisig upgrades — high value, low frequency.



Why We Need Precompiles

Scheme	Pure Solidity	Precompile	Reduction
ML-DSA (NIST)	13.0M gas	4,500 gas	∼2,900×
ML-DSA-ETH	8.3M gas	4,500 gas	∼1,800×
Falcon (NIST)	4.1M gas	3,000 gas	∼1,370×
Falcon-ETH	1.6M gas	3,000 gas	∼530×
ECDSA (ref.)	*3,000 gas*	—	—

With precompiles, PQ signature verification cost becomes comparable to ECDSA. The dominant cost of a PQ transaction is then the **UserOp handling itself**, not the cryptography.

NIST candidates (pros and cons)

Standardization since 2016... and ~~the winner is~~ the winners are:

- **Dilithium – ML-DSA**, based on lattices,
- **Falcon – FN-DSA**, based on lattices,
- SPHINCS – SLH-DSA, based on hash functions (big and expensive)

How to choose?

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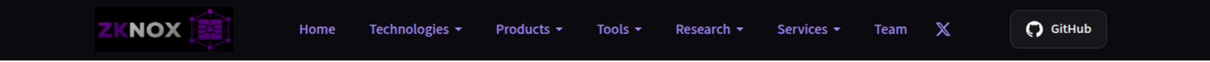
How to choose?

	ML-DSA	**FN-DSA**
EIP	8051	8052
Public key	1312B	897B
Signature	2420B	666B
On-chain cost	13.0M gas (8.3M gas)	4.1M gas (1.6M gas)
Standardized?	FIPS 204	not yet (since 2 years)
Signer implementation	Easy, many	Tricky, floating point
Hardware integration	Done	High RAM requirements
Industrial integration	Passkey, Apple (soon)	no
ZK variant	Possible	Overstretch attacks



EIPs 8051 and 8052

- **EIP 8051**: link
  - Two precompiles:
    - MLDSA: NIST-compliant with SHAKE256 (verification: 13.0 M gas, not far from the tx limit of 16M!).
    - MLDSA-ETH: replacement with a counter-mode Keccak PRNG (verification: 8.3M gas).
  - Test vector provided (generated from NIST reference implementation).
  - Integrated into a 4337 hybrid (MLDSA + ECDSA) account: Try it by yourself!

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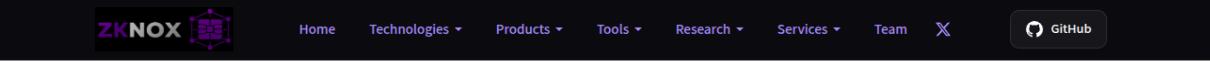
- **EIP 8052**: link
  - Separation of the hash part and the polynomial arithmetic:
    - FALCON: NIST-compliant with SHAKE256 (verification: 4.1M gas).
    - ETH-FALCON: replacement with a counter-mode Keccak PRNG (verification: 1.6M gas).
  - Precompiles for FALCON-CORE and HASH-TO-POINT (one for Shake256, one for KeccakPRNG).
  - Test vector provided (generated from NIST reference implementation).
  - Integration in a 4337 account in progress...



Live Demo: Post-Quantum DeFi on Sepolia

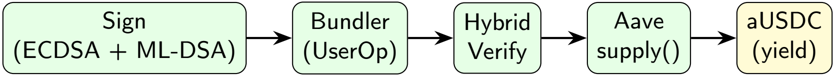
Demo: visionary-nougat-217eaa.netlify.app

What it does:

1. Connect with PQ-enabled signer
2. Hybrid signature (ECDSA + ML-DSA)
3. Supply USDC to Aave V3 (Sepolia)
4. Earn yield with quantum-safe keys

Stack:

- ERC-4337 smart account
- Modular hybrid verifier
- Pure Solidity PQ verification
- Standard Aave V3 interaction
- No protocol modification needed



Sign (ECDSA + ML-DSA) → Bundler (UserOp) → Hybrid Verify → Aave supply() → aUSDC (yield)