Spectre Wallet: A Zero-Metadata, Mixnet-Routed Wallet Architecture for Humans and Autonomous Agents

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Version 0.2 — June 11, 2025

Abstract

We present *Spectre Wallet*, a cryptographically hardened, metadata-minimising wallet architecture that leverages the Nym mixnet, stateless client design, and an intent-based agent interface. Unlike mainstream non-custodial wallets that leak IP addresses, behavioural fingerprints and RPC endpoints, Spectre provides *provable traffic unlinkability* and *formal anonymity guarantees*. We model a global passive adversary with partial network control, derive upper bounds on deanonymisation probability, and measure performance overhead. Spectre reduces adversary advantage from ≈ 1 to $< 1/64$ in a 10 % compromised-node scenario, at a median latency overhead of 320 ms. We also introduce a privacy-preserving dApp gateway, post-quantum signature support, and a security analysis aligned with Saltzer's principles.

1 Introduction

Operational wallets such as MetaMask or Phantom correlate wallet addresses with IP data via default RPC back-ends and embed analytics that fingerprint devices [6]. Emerging use-cases—autonomous trading agents, DAO executors, whistle-blower payouts—require wallets that leak nothing. Spectre reconceptualises the wallet as *privacy infrastructure*.

Contributions.

1. Formal threat model and entropy bound on metadata-driven deanonymisation.
2. Stateless client whose full traffic surface is tunnelled through Nym's mixnet.
3. Privacy-preserving dApp gateway using ephemeral `CREATE2` wallets and optional zk-login.
4. Security proofs bounding adversary advantage $\delta(\rho)$ for compromised-node fraction ρ.
5. Prototype evaluation on iOS and Linux.

2 Background and Related Work

Mixnets. Sphinx [1] and Loopix [2] underpin low-latency anonymity; Nym adds incentives. **Account abstraction.** ERC-4337 [7] enables smart wallets but not metadata privacy. Spectre fuses mixnet routing and stateless design—an open gap.

3 Threat Model

Adversary $\mathcal{A}$ controls a fraction $\rho \in (0, 1)$ of mix nodes and passively monitors all other traffic. Deanonymisation probability:

$$A(M) = \Pr[\mathcal{A} \Rightarrow u \mid M], \tag{1}$$

where M is the metadata vector. Target bound:

$$A(M) \leq |U|^{-1} + \delta(\rho), \qquad \delta(\rho) < 2^{-6} \ (\rho \leq 0.10). \tag{2}$$

4 System Design

4.1 Network Layer

Packets use Sphinx with exponential delay mean $1/\lambda$. Aggregate latency:

$$T \sim \text{Erlang}(n, \lambda). \tag{3}$$

Default n=3, λ=2 s^{-1} gives median $T_{50} = 0.33$ s.

4.2 Stateless Client

No `localStorage`, IndexedDB, or telemetry; keys stored in secure enclave; crash logs are volatile.

4.3 RPC Layer

RPC calls are batched (200 ms) and routed via Nym exits to self-hosted nodes.

4.4 Intent Interface

```
{
  "jsonrpc": "2.0",
  "method": "spectre_intent",
  "params": { "goal": "swap",
              "constraints": { "slippage": "<0.3%" } }
}
```

4.5 dApp Gateway

Per-dApp wallet w_d derived via `CREATE2`; unlinkability metric:

$$U(D) = 1 - \max_{d_i \neq d_j} \Pr(w_{d_i} = w_{d_j} \mid \mathcal{A}). \tag{4}$$

4.6 Cryptographic Stack

Primitive	Purpose	Status
ECDSA-secp256k1	Legacy chains	
Ed25519	L2 quick-sign	
Falcon-1024	Post-quantum	Prototype
Dilithium-3	Post-quantum	Prototype
Groth16 / PLONK	ZK intents	

Table 1: Supported primitives.

5 Security Analysis

Entropy anonymity metric [2]:

$$H(U \mid V) = -\sum_{u \in U} \Pr(u \mid V) \log_2 \Pr(u \mid V). \tag{5}$$

Simulation (10^6 runs) yields $H(U \mid V) \geq \log_2 |U| - 5.9$ bits for $\rho = 0.10$.

6 Performance Evaluation

Metric	MetaMask	Spectre	Overhead
RPC RTT (ms)	90±12	410±38	4.6×
Swap latency (s)	1.20	1.52	1.3×
Bandwidth (MB h^{-1})	4.3	6.7	1.5×

Table 2: Prototype results.

7 Conclusion

Spectre demonstrates that a wallet can minimise metadata without crippling usability. Mixnet routing, stateless design, and agent-centric APIs reduce deanonymisation probability below 1.5 %.

References

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