

A Zero-Native-Dependency Post-Quantum Cryptographic Toolkit for Node.js: HPKE, LSH-256, and BB84 QKD

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Abstract—Post-quantum cryptographic libraries for JavaScript/Node.js typically rely on native C/C++ addons or WebAssembly modules, introducing supply-chain risk and cross-platform compilation challenges. We present a zero-native-dependency post-quantum cryptographic toolkit implemented entirely using Node.js built-in crypto primitives (OpenSSL-backed). The toolkit includes: (1) a complete HPKE implementation (RFC 9180) supporting Base, PSK, Auth, and AuthPSK modes with DHKEM(X25519), HKDF-SHA256, and AES-256-GCM or ChaCha20-Poly1305; (2) LSH-256-256 (KS X 3262), a Korean standard hash function with 128-bit post-quantum collision resistance; and (3) a BB84 quantum key distribution simulation with basis reconciliation, eavesdrop detection, and privacy amplification. We describe the implementation approach, verify correctness against reference test vectors, and discuss the design principle of maximizing quantum resistance while minimizing dependency surface.

Index Terms—post-quantum cryptography, HPKE, LSH-256, BB84 QKD, Node.js, zero dependencies, supply-chain security

I. Introduction

The JavaScript ecosystem’s reliance on deeply nested dependency trees creates supply-chain attack surfaces that are particularly concerning for cryptographic libraries. Incidents like the event-stream compromise [4] and uaparser-js malware injection [5] demonstrate that npm dependencies are active attack vectors.

For cryptographic code—where a single compromised dependency can undermine all security guarantees—the ideal is zero external dependencies. Node.js (v18+) provides a comprehensive crypto module backed by OpenSSL, offering SHA-3, AES-GCM, X25519 key exchange, ChaCha20-Poly1305, HKDF, and other primitives sufficient to construct advanced cryptographic protocols.

We demonstrate this approach by implementing three post-quantum-relevant cryptographic systems using only platform-native primitives:

- 1) HPKE (RFC 9180): Hybrid Public Key Encryption with PSK mode for harvest-now-decrypt-later (HNDL) defense.
- 2) LSH-256-256 (KS X 3262): A hash function with 128-bit collision resistance under Grover’s algorithm.
- 3) BB84 QKD Simulation: Quantum key distribution with eavesdrop detection.

II. Design Principles

A. Zero Native Dependencies

All cryptographic operations use exclusively node:crypto APIs. No native C/C++ addons, no WebAssembly modules, no node-gyp compilation. This eliminates:

- Binary supply-chain attacks through compromised native modules
- Cross-platform build failures
- Version-specific ABI incompatibilities
- Audit complexity (the entire crypto surface is Node.js + OpenSSL)

B. Post-Quantum Security Tiers

We classify supported algorithms into tiers:

TABLE I
Cryptographic Algorithm Tiers

Tier	Algorithms	PQ Security
HIGH	LSH-256-256, AES-256-GCM, ChaCha20-Poly1305, HPKE-PSK	128-bit
MODERATE	SHA3-256/512, HMAC-SHA3, HKDF-SHA3, SHAKE256	128-bit (hash only)

III. HPKE Implementation (RFC 9180)

A. Overview

Hybrid Public Key Encryption [1] combines asymmetric key encapsulation with symmetric encryption. Our implementation supports:

- KEM: DHKEM(X25519, HKDF-SHA256)
- KDF: HKDF-SHA256
- AEAD: AES-256-GCM, ChaCha20-Poly1305
- Modes: Base, PSK, Auth, AuthPSK

B. PSK Mode for HNDL Defense

The PSK (Pre-Shared Key) mode is particularly relevant for post-quantum security. In HNDL attacks, adversaries record encrypted traffic today to decrypt with future quantum computers. HPKE-PSK mode provides defense:

$$K = \text{Extract}(\text{PSK} \parallel \text{shared_secret}) \quad (1)$$

Even if the X25519 key exchange is broken by a quantum computer, the PSK component remains secure, protecting the session key. This provides a practical post-quantum defense without requiring lattice-based or code-based KEMs.

C. Implementation Details

Key encapsulation uses `crypto.generateKeyPairSync('x25519')` for ephemeral key generation, `crypto.diffieHellman()` for shared secret computation, and `crypto.hkdf()` for key derivation. AEAD operations use `crypto.createCipheriv()` and `crypto.createDecipheriv()`.

D. Test Vector Verification

We verified our implementation against the RFC 9180 test vectors (Appendix A) for all four modes. All 12 test cases pass, confirming interoperability with other HPKE implementations.

IV. LSH-256-256 Implementation (KS X 3262)

A. Algorithm Description

LSH [2] is a hash function standardized as KS X 3262 by the Korean Agency for Technology and Standards. LSH-256-256 produces a 256-bit digest with the following properties:

- Internal state: 1024 bits (sixteen 32-bit words)
- Rounds: 26 steps, each applying ARX (Add-Rotate-XOR) operations
- Block size: 1024 bits
- Classical collision resistance: 128 bits
- Quantum collision resistance: 128 bits (Grover provides no advantage for collision search on wide-state hashes)

B. Implementation

The LSH-256 implementation uses only JavaScript arithmetic operations and Buffer manipulation:

- 1) Message padding: Append 1-bit, zero-pad to 1024-bit boundary, append 64-bit length.
- 2) Initialization: Load 16-word IV (defined in KS X 3262).
- 3) Step function: For each of 26 steps, apply word-level addition (mod 2^{32}), bitwise rotation by step-dependent constants, and XOR mixing across word pairs.
- 4) Finalization: XOR upper and lower halves of state, truncate to 256 bits.

C. Performance

The pure JavaScript implementation is naturally slower than OpenSSL-backed alternatives. However, for security-critical applications where the hash is applied to small inputs (keys, tokens, digests), the throughput is sufficient. The trade-off is explicit: we accept lower throughput in exchange for zero native dependencies and auditability.

TABLE II
Hash Function Performance (1MB input)

Algorithm	Implementation	Throughput
SHA-256	Node.js built-in (OpenSSL)	850 MB/s
SHA3-256	Node.js built-in (OpenSSL)	420 MB/s
LSH-256-256	Pure JS (ours)	45 MB/s

V. BB84 QKD Simulation

A. Protocol

BB84 [3] enables two parties (Alice and Bob) to establish a shared secret key with information-theoretic security, assuming an authenticated classical channel.

Our simulation implements:

- 1) Qubit preparation: Alice randomly selects bits and bases (rectilinear + or diagonal \times), generating N qubits.
- 2) Measurement: Bob randomly selects measurement bases. Matching bases yield correlated bits.
- 3) Basis reconciliation: Alice and Bob publicly compare bases (not bit values), discarding mismatched measurements.
- 4) Eavesdrop detection: A subset of reconciled bits is compared. Error rate $> 11\%$ indicates eavesdropping (Eve).
- 5) Privacy amplification: Universal hashing reduces Eve's information to negligible levels.

B. Integration with Threat Detection

QCrypton uses BB84-derived keys for a specific purpose: encrypting detected secrets before they appear in scan reports. This ensures that even if the reporting pipeline is compromised, plaintext credentials are never exposed.

VI. Crypto-Agility via HSM Abstraction

The toolkit includes an HSM/KMS abstraction layer supporting post-quantum algorithms through external hardware:

- ML-KEM (512/768/1024): NIST PQC standard for key encapsulation
- ML-DSA (44/65/87): NIST PQC standard for digital signatures
- SLH-DSA: Stateless hash-based signatures

Supported backends: Entrust nShield, AWS KMS, Azure Key Vault, Google Cloud KMS, Thales Luna. Algorithm selection is configuration-only, enabling hot-swap without code changes.

VII. Related Work

`libsodium.js` [6] provides NaCl-compatible crypto via Emscripten/WASM but introduces binary dependencies. `node-forge` [7] implements TLS in pure JS but lacks post-quantum primitives. CRYSTALS-Kyber JS implementations [8] use WASM. Our approach is unique in providing post-quantum-relevant protocols (HPKE-PSK, LSH-256) with strictly zero native or WASM dependencies.

VIII. Conclusion

We demonstrate that meaningful post-quantum cryptographic capabilities can be built using only Node.js platform primitives, eliminating supply-chain risk in the cryptographic layer. The HPKE-PSK mode provides practical HNDL defense today, LSH-256-256 offers Grover-resistant hashing, and BB84 QKD simulation enables quantum-safe key derivation for sensitive operations. The performance trade-off is acceptable for security-critical, low-throughput applications where auditability and dependency minimization outweigh raw speed.

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