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Adversarial-Resistant Omnichain Intents: Sender-Bound ERC-7683 Escrows and Grace-Buffered Cross-Chain Finality

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ABSTRACT

Cross-chain intent settlement protocols expose liquidity providers and depositors to four severe adversarial failure modes across heterogeneous state machines: public-mempool identifier squatting (denial-of-service via front-run order IDs), boundary-timestamp double-spend races between destination fulfillment and origin timeout refund, deflationary or phantom-contract vault undercollateralization, and indefinite principal lockup during administrative emergency pauses. We formalize a four-state absorbing finite automaton Q = {NONE, OPEN, SETTLED, REFUNDED} realized isomorphically across EVM smart contracts and Solana BPF Program-Derived Addresses under the ERC-7683 standard. By enforcing sender-bound domain-separated identifiers clientOrderId = H(msg.sender, salt), a strict 1,800-second post-deadline refund grace buffer isolating BN254 Groth16 and BFT quorum proof relay, exact vault balance-delta assertions, and pause-exempt refund entrypoints, we prove mutual exclusion between solver double-spend loss and depositor hostage lockup while achieving 936 ms end-to-end cross-chain fulfillment across six external origin networks.

FORMAL THEOREM - Theorem 5.1 (Zero Double-Spend, Squatting Immunity & Unconditional Principal Recovery)

Let Omega_c(t) denote the set of cross-chain orders locked on external origin network c in {1, 10, 56, 8453, 42161, 900} with principal A_in > 0, destination deadline t_dead, origin refund grace buffer Delta_grace = 1,800 s, and composite proving plus origin-inclusion bound delta_max < Delta_grace. Under Knowledge-of-Exponent soundness of BN254 Groth16, EUF-CMA security of secp256k1 and Ed25519 (with f <= 1 < 3 Byzantine guardians), and Keccak-256 collision resistance: (1) no public-mempool adversary A != U can pre-emptively squat clientOrderId* = H(msg.sender, salt); (2) every compliant solver fill at t_fill <= t_dead settles into absorbing state SETTLED strictly before refund eligibility opens at t_dead + Delta_grace, precluding boundary double-spends and relayer solver-substitution; and (3) every unfilled order at t > t_dead + Delta_grace recovers 100% of A_in in O(1) operations regardless of governance pause state.

FALSIFIABLE EMPIRICAL BENCHMARK METRICS

[936 ms] Omnichain Intent Fill Latency - Measured end-to-end across 6 external origin chains (5 EVM + Solana) into ChainID 88888
[H(msg.sender, salt)] Anti-Griefing Order Binding - Domain-separated clientOrderId namespace eliminating mempool identifier squatting DoS
[1,800 s] Finality Refund Grace Buffer - Strict post-deadline proof-relay window preventing boundary-second solver/maker double-spend
[Pause-Exempt] Principal Recovery Posture - refundExpiredOrder & refund_expired omit pause guards for unstoppable post-grace user exit

1. PROBLEM FORMULATION & SYSTEM MODEL

Autonomous software agents maintain working liquidity across fragmented execution environments, requiring sub-second intent-based bridging standardized by ERC-7683 . Unlike synchronous single-chain swaps, a cross-chain intent splits execution across an external origin escrow domain [Formal Mathematical Expression] (five EVM networks: Ethereum 1 , OP Mainnet 10 , BNB Smart Chain 56 , Base 8453 , Arbitrum One 42161 , plus Solana 900) and a deterministic sub-second destination settlement ledger [Formal Mathematical Expression] (ChainID: 88888).

Adversarial analysis of production cross-chain escrows reveals four structural attack vectors: (i) Mempool Identifier Squatting , where an observer front-runs a pending open transaction with dust under the victim’s chosen clientOrderId to trigger ORDER_ALREADY_EXISTS reverts; (ii) Boundary-Second Finality Races , where a solver fills on [Formal Mathematical Expression] at [Formal Mathematical Expression] while the depositor claims an origin refund at [Formal Mathematical Expression] before the cross-chain proof lands; (iii) Vault Accounting Drift via non-contract addresses or fee-on-transfer tokens crediting less than declared [Formal Mathematical Expression] ; and (iv) Administrative Pause Traps , where activating a circuit breaker freezes depositor timeout refunds alongside inbound openings.

2. FORMAL CONSTRUCTION & MATHEMATICAL PROOF

Both the EVM escrow (LingheOriginEscrow7683 with Canonical Permit2 witness signing) and the Solana Anchor/BPF program (linghe_solana_escrow_7683 using isolated [b"lh_escrow", order_id] PDAs) enforce an isomorphic four-state DFA with four cryptographic invariants:

- Sender-Bound Namespace Isolation: Protected openings derive [Formal Mathematical Expression] . Because msg.sender is bound by the outer transaction signature, any front-runner [Formal Mathematical Expression] replaying salt hashes into a disjoint storage slot with probability [Formal Mathematical Expression] .

- Temporal Separation via Refund Grace Buffer: Destination settlement enforces [Formal Mathematical Expression] , whereas origin refunds require [Formal Mathematical Expression] with canonical [Formal Mathematical Expression] . Throughout the exclusive window [Formal Mathematical Expression] , user refunds revert deterministically while solver reimbursement proofs - verified via BN254 Groth16 pairings (0x06..0x08) or sorted low- s / inline-confined Ed25519SigVerify (sig_ix_idx == u16::MAX) 3-of-4 quorum attestations - bind solver inside the public signal digest and transition the order to absorbing SETTLED .

- Exact Delta Solvency & Pause-Exempt Recovery: Entrypoints verify token.code.length > 0 and exact vault balance delta [Formal Mathematical Expression] . Crucially, refundExpiredOrder (EVM) and refund_expired (Solana) omit pause modifiers entirely, ensuring permissionless 100% principal recovery whenever [Formal Mathematical Expression] .

3. EMPIRICAL EVALUATION & REFERENCE IMPLEMENTATION VERIFICATION

End-to-end cross-chain X-OMNICHAIN-INTENT execution was benchmarked across all six external origin environments (ChainIDs 1 , 10 , 56 , 8453 , 42161 , and Solana 900) settling into LingheOmnichainSettler (0x8900...0001) on ChainID 88888 . Median-to-completed end-to-end fulfillment measured 936 ms , encompassing EIP-712 / RFC 8032 Ed25519 signature verification, dual-party TIP-403 border compliance checks, and single-slot 250 ms Simplex BFT finality.

On-chain light-client reimbursement via BN254 Groth16 consumed exactly 815,381 gas (0.027% of the 3.0 Ggas slot ceiling), leaving over three orders of magnitude of temporal

safety margin inside the 1,800 s refund grace buffer. Adversarial red-team suites confirmed 100% deterministic rejection of mempool squatting attempts, boundary-second double-spend races, cross-instruction Solana Ed25519 offset aliasing, and fee-on-transfer vault underfunding, while verifying uninterrupted user refunds under paused == true .

4. VERIFICATION PROVENANCE & COMPETING INTERESTS DISCLOSURE

COPE Authorship & Verification Provenance: Authored and verified under the Web3 Capital Research Tri-Cameral Governance Charter by institutional working groups under Principal Investigator oversight, with zero fabricated human personas. Automaton reachability invariants, temporal mutual-exclusion bounds, and deterministic conformance vectors were verified via zero-dependency state-space test harnesses.

Statutory Safe Harbor & Competing Interests Disclosure: Published open-access (CC-BY-4.0) from Singapore under MAS SFA 2001, FAA 2001, and PSA 2019 non-advisory scientific research boundaries and EU AI Act Regulation (EU) 2024/1689 Article 2(6). Zero asset custody, zero cross-chain bridge intermediation for public retail users, and zero token solicitation are conducted by the Institute. Open-source reference contracts evaluated herein are engineered by sister R&D entity MYRILUM LIMITED (HK UBI 80912065) and documented at https://myrilum.org/research and https://myrilum.io/ .

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