Code-Snippet

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# EchoPulse Critical Enhancements — Patch 6.2 **Version:** 6.2
**Date:** May 11, 2025 **Author:** EchoPulse Initiative This document
details critical enhancements to the EchoPulse protocol resolving
advanced security, determinism, and symbolic inference issues
identified during an expert audit of specification files 4 to 6 within
the EchoPulse dossier. ## 1. Path Entropy Clarification The effective
entropy of a symbolic path of length $l$ within the state transition
graph $G(V, E)$ with an average out-degree $d$ is reaffirmed as:
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$$\text{Entropy} \approx l \times \log_2(d)$$

```
For instance, a path length of $l = 28$ with an average out-degree $d =
24$ ($\log_2(24) \approx 4.58$) yields approximately 128 bits of
entropy. Crucially, the selection of symbols within these paths,
particularly in $r$, must exhibit a near-uniform distribution across $\
Sigma = 256$ to prevent statistical leakage. ## 2. Fallback & Collision
in Symbol Sequences (r) In scenarios where decapsulation fails,
potentially due to temporary graph desynchronization or subtle symbol
drift, the random symbol sequence $r$ should be re-generated. A safe
re-derivation mechanism for retrying encapsulation is suggested:
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$$r' = H(\text{session\_index} \,||\, \text{encapsulation\_seed})$$

```
where `encapsulation_seed` is a fresh random value generated for the
retry. ## 3. SK to PK Determinism & Prefix Collision Prevention When
the public key $PK$ is derived deterministically from the secret key
$SK$ during KeyGen, the derivation process must incorporate a unique
salt or fingerprint (e.g., $H(\text{master_seed} || \
text{device_identifier})$) to mitigate potential prefix similarity
across different key pairs. Furthermore, the symbolic paths
corresponding to $SK$ and $PK$ within $G(V, E)$ should be mapped
orthogonally to minimize correlation. This can be achieved through the
use of non-overlapping sets of transition symbols or by injecting a
distinct salt-dependent path offset during the $PK$ derivation
traversal. ## 4. Replay & Session Locking in Mutation The mutation
function $\mu(G, \text{salt}, \text{session_index})$ must enforce
bounds on the acceptable range of `session_index` values to prevent
unbounded replay attacks targeting graph evolution. A recommended
approach is to use HMAC chaining with a trusted domain-specific seed
and a temporal parameter $t$ (e.g., uptime) to derive a bounded session
index:
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$$\text{effective\_session\_index} = H(\text{seed} \,||\, t) \bmod k$$

```
where $k$ defines the window of valid session indices. ## 5. Mutations
per Session: Frequency & Memory Strategy A default mutation frequency
of every 10 encapsulation events or a 24-hour uptime window (whichever
occurs first) is suggested to balance security and computational
overhead. For devices with less than 64 KB of RAM, managing graph
mutations efficiently is critical. Strategies include: * **Rolling
Graph Overlay:** Store only the changes (deltas) to the graph between
mutation intervals and apply these overlays to a base graph. * **2-
Slice Precompute:** Precompute the graph state for the current and next
mutation intervals. Apply the delta incrementally as the session count
approaches the next mutation point. ## 6. AI Pattern Resistance in
SK/PK Prefixes To counter potential Transformer-style sequence learning
attacks targeting the prefixes of $SK$ and $PK$, the following
countermeasures should be implemented during key generation: *
**Randomized Symbol Start Point:** Introduce a small, random offset in
the starting position within the symbol sequence. * **Dummy Prefix
Injection:** Prepend a short sequence of random "dummy" symbols to the
actual $SK$ sequence. * **Symbolic Boundary Noise:** When deriving $PK$
from $SK$, enforce a small, deterministic but pseudo-random
perturbation (noise injection) at defined intervals within the symbolic
sequence to disrupt the learning of direct sequential dependencies. ##
7. Conclusion This patch consolidates critical enhancements addressing
potential edge cases and advanced adversarial strategies identified
during expert audit. By clarifying path entropy, ensuring robust
handling of symbol sequence collisions, enforcing determinism and
orthogonality in key derivation, locking session indices, optimizing
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