Authority Propagation Models: PoP vs PoC and the Confused Deputy Problem

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1 Model

We formalize the PIC (Provenance Identity Continuity) Model as follows.

Let P be a finite set of principals, O a set of operations, and R a set of resources. Define a privilege as $(o, r) \in O \times R$.

Execution is modeled as a causal chain of hops:

$$\pi = \langle (p_0, ops_0), (p_1, ops_1), \ldots, (p_n, ops_n) \rangle$$

where p_0 is the originator and each $ops_{i+1} \subseteq ops_i$ (monotonicity).

Definition 1 (PIC Model)**.** *A system enforces Provenance Identity Continuity if, for every execution chain π, the set of privileges at the final hop is bounded by the privileges at the origin:*

$$ops_n \subseteq ops_0$$

and every privilege exercised at hop n is causally linked to the origin via a verifiable chain.

Theorem 1 (PIC Safety)**.** *If the PIC Model holds, no principal can exercise a privilege not present at the origin.*

Proof. By construction, $ops_{i+1} \subseteq ops_i$ for all i, so $ops_n \subseteq ops_0$. Thus, any $(o, r) \in ops_n$ must also be in ops_0. Therefore, no privilege can be gained beyond the origin.

Each principal p has an associated privilege set:

$$Priv(p) \subseteq O \times R.$$

A request is a message req sent between principals and may contain a payload.

2 Confused Deputy

Definition 2 (Confused Deputy)**.** *A confused deputy occurs when there exist principals U (user) and D (deputy) such that:*

1. $(o, r) \notin Priv(U)$,
2. $(o, r) \in Priv(D)$,
3. *U sends a request req to D,*
4. *as a consequence of req, D executes (o, r).*

This definition does not depend on implementation details, only on the mismatch of authority and causality.

3 Proof-of-Possession (PoP)

A token t grants a set of privileges:

$$Auth(t) \subseteq O \times R.$$

PoP Semantics: Possession implies usability: if a principal holds t, it may exercise all $(o, r) \in Auth(t)$.

PoP systems do not constrain authority by causality or provenance.

3.1 Vulnerability Condition

Assume:

$$(\text{delete}, r) \notin Priv(U) \tag{H1}$$
$$(\text{delete}, r) \in Priv(PDF) \tag{H2}$$

Further assume:

> The payload of a request may influence control flow in PDF, including code paths that call internal privileges such as delete.

Theorem 2 (PoP admits confused deputy)**.** *Under assumptions (H1)–(H2), there exists a request req such that PDF executes $(delete, r)$ as a result of processing req.*

Proof. Since $(\text{delete}, r) \in Priv(PDF)$ (H2), some code path in PDF invokes Storage.delete(r). Because processing is influenced by payload, there exists an adversarial payload that triggers that path. Since U lacks (delete, r) (H1), and PDF acts on behalf of U, conditions for a confused deputy are satisfied.

This applies to OAuth tokens and sealed capabilities: sealing protects transport, not authority semantics.

4 Proof-of-Continuity (PoC / PIC)

Execution is modeled as a causal chain of hops:

$$p_0 \to p_1 \to \cdots \to p_n,$$

with $p_0 = U$.

Each hop transfers a privilege subset:

$$ops_i \subseteq O \times R$$

and must satisfy:

$$ops_{i+1} \subseteq ops_i. \tag{C1}$$

Let π be a verifiable sequence:

$$\pi = \langle (p_0, ops_0), (p_1, ops_1), \ldots, (p_n, ops_n) \rangle.$$

4.1 Authorization Rule

The final service authorizes (o, r) if and only if:

$$(o, r) \in \bigcap_{i=0}^{n} ops_i$$

and π is valid.

Since the chain is monotonic decreasing,

$$\bigcap_{i=0}^{n} ops_i = ops_n.$$

Thus no hop may acquire new authority not present at the origin.

5 Safety Property

Definition 3 (Origin-bounded authority)**.** *A model enforces origin-bounded authority if every executable privilege at hop n is a privilege originally granted by hop 0.*

Theorem 3 (PoC prevents confused deputy)**.** *If $ops_0 = \{(convert, r)\}$ and (C1) holds for every hop, then $(delete, r)$ can never be authorized at hop n.*

Proof. Authorization requires:

$$(\text{delete}, r) \in \bigcap_{i=0}^{n} ops_i.$$

But $(\text{delete}, r) \notin ops_0$ and each $ops_{i+1} \subseteq ops_i$. Therefore $(\text{delete}, r) \notin ops_i$ for all i, hence not in the intersection. The request is rejected.

6 Discussion

PoP systems conflate authority and possession, enabling confused deputy attacks whenever privileged internal code paths exist. PIC/PoC systems propagate only non-expansive subsets of authority, ensuring that downstream services cannot perform operations not explicitly authorized at the origin.

Related Work

The confused deputy was originally formalized by Hardy (1988), showing how ambient authority enables unintended privilege escalation. Earlier foundations of capability systems date back to Dennis and Van Horn (1966), while confinement and controlled execution were explored by Lampson (1973). Modern capability systems such as EROS (Shapiro et al., 1999) and seL4 (Klein et al., 2009) provide strong isolation properties and monotonic privilege enforcement. The formal theory of distributed authorization and delegation traces back to Abadi et al. (1993–2000) and the SPKI certificate model (RFC 2693). Recent identity systems such as BeyondCorp and SPIFFE apply similar causal principles to zero-trust environments.

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ideas, models, proofs, and conclusions in this document are solely the responsibility of the author.

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