DPolicy: Managing Privacy Risks Across Multiple Releases with Differential Privacy

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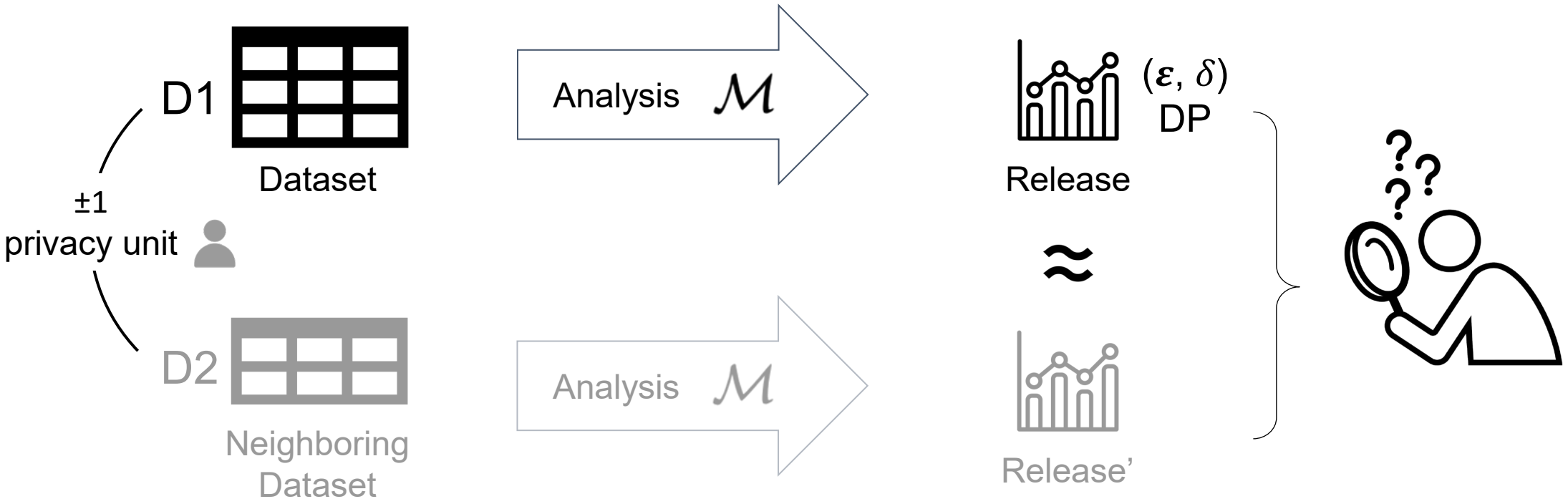
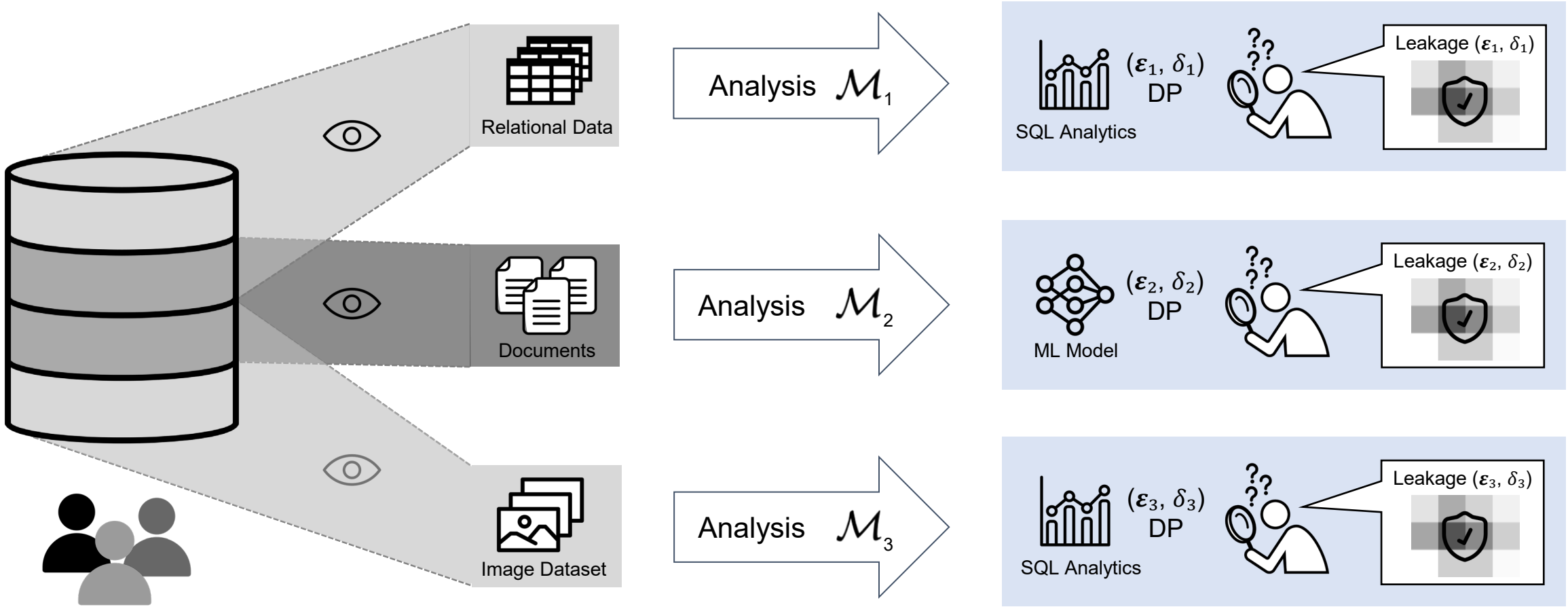
Differential Privacy



$$Pr\left[\mathcal{M}(D_1) \in \mathcal{S}\right] \leq e^{\epsilon} \cdot Pr\left[\mathcal{M}(D_2) \in \mathcal{S}\right] + \delta$$

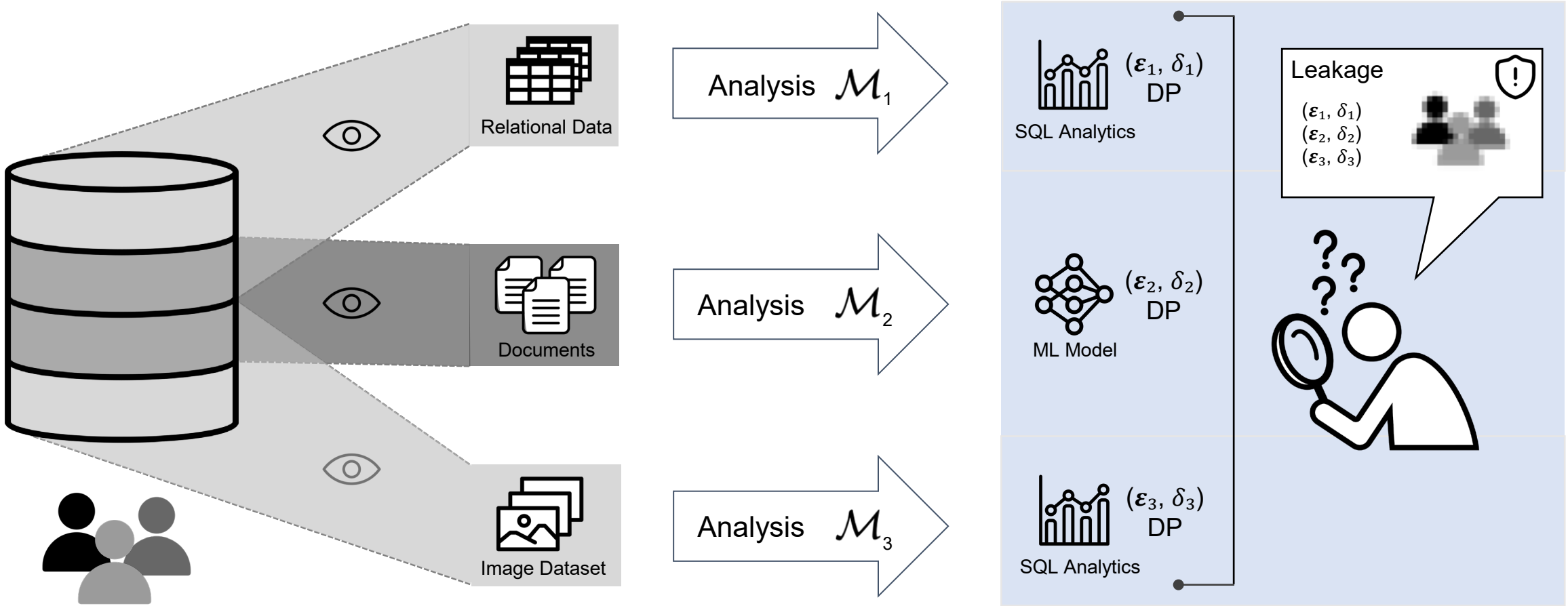
Differential Privacy

For managing risks at an organizational scale

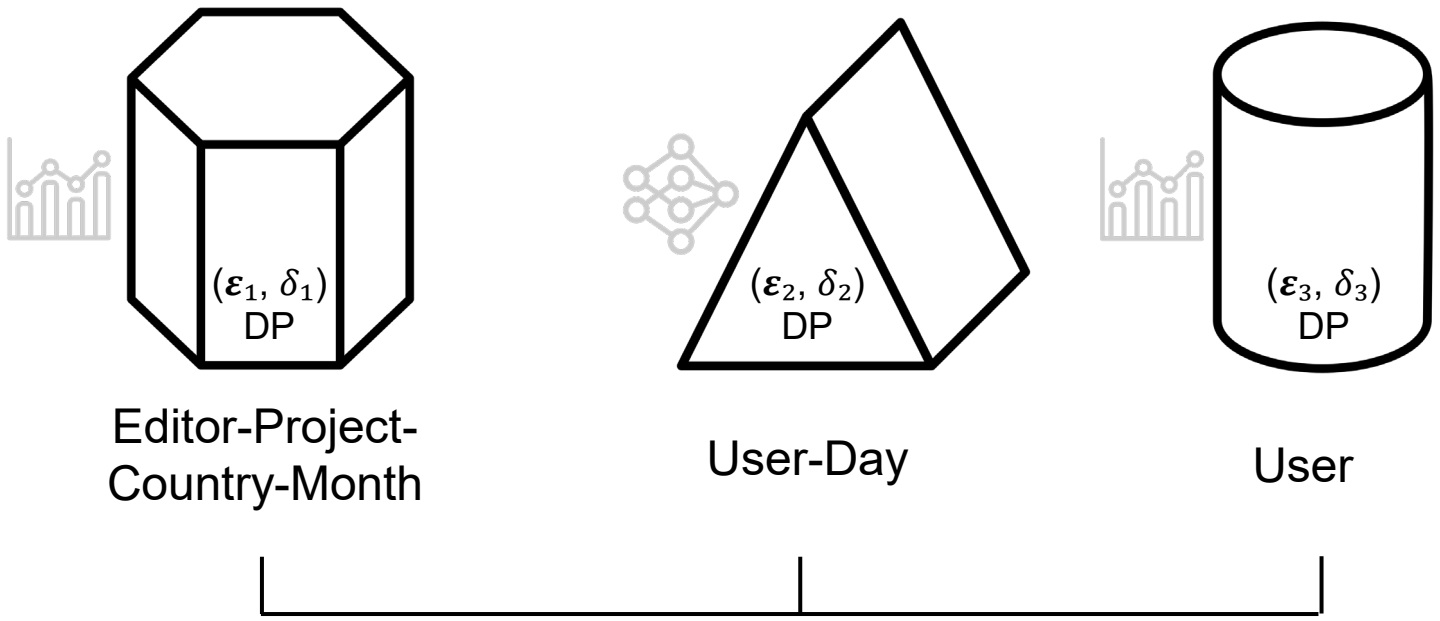


Differential Privacy

For managing risks at an organizational scale



Problem 1: **Release-specific Privacy Unit**

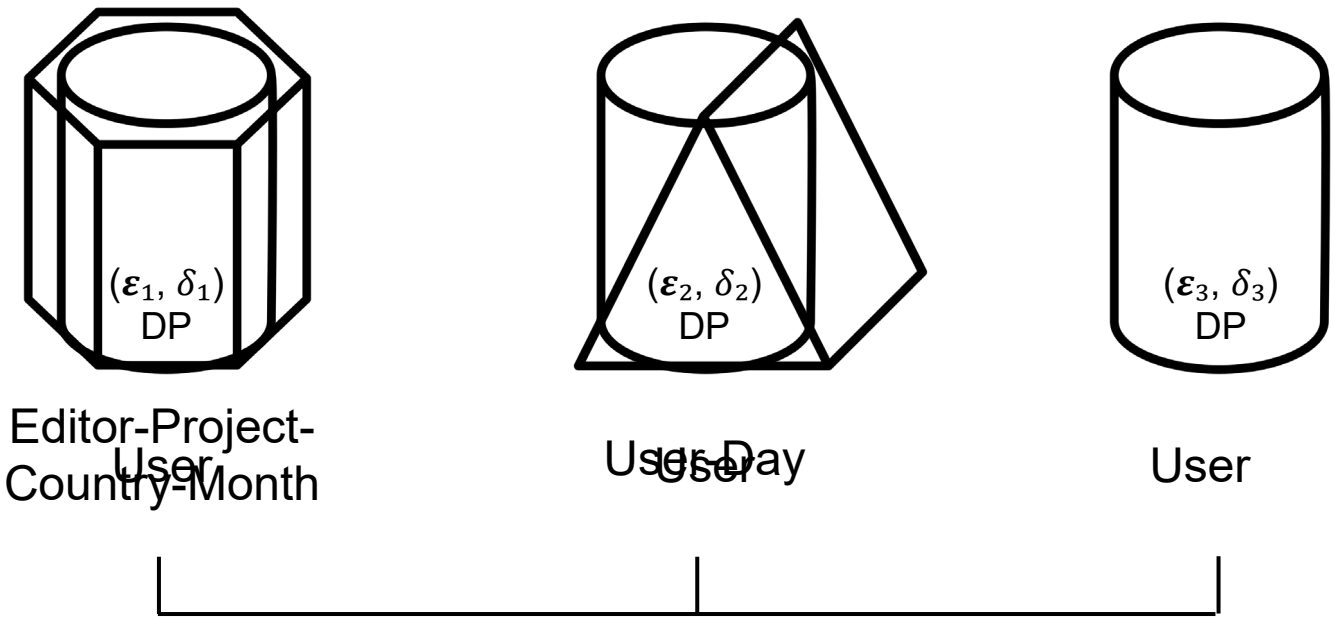


Privacy Units: Reasonable in Isolation but **Hard to Combine**

Real-World DP Uses
[Desfontaines, 2021]

Unified Privacy Unit

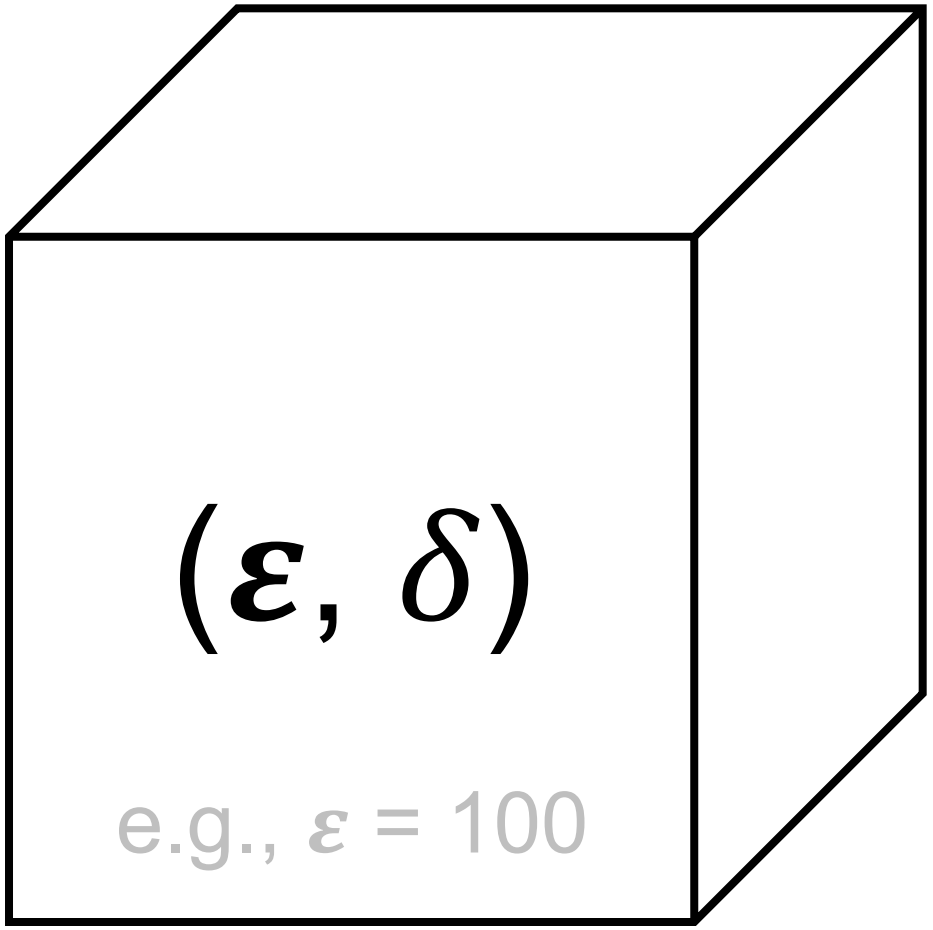
Enabling composition across all releases



$$(\varepsilon_1, \delta_1) + (\varepsilon_2, \delta_2) + (\varepsilon_3, \delta_3) + \ldots \leq (\varepsilon, \delta)$$

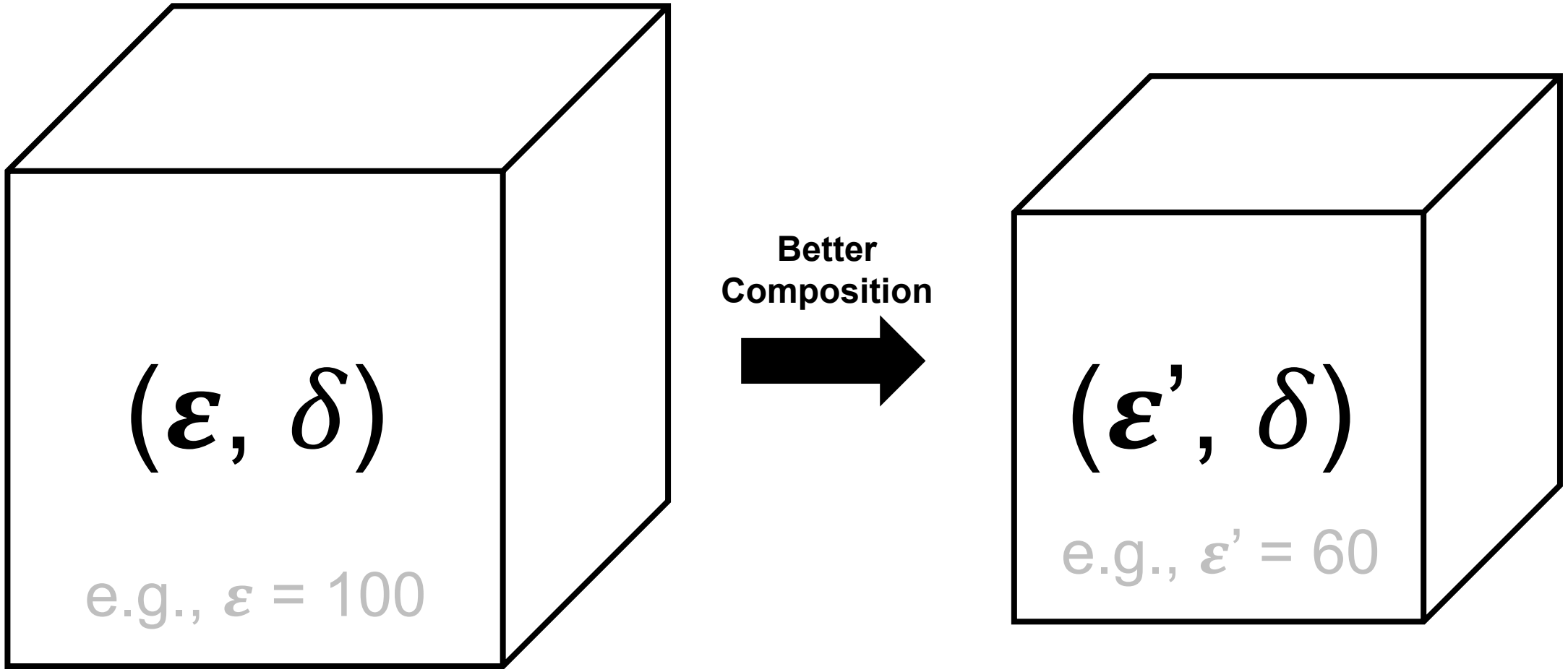
Problem 2: **Large Privacy Budget**

With limited mathematical meaning

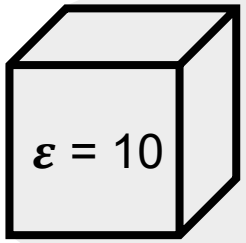


Problem 2: **Large Privacy Budget**

With limited mathematical meaning



Problem 3: **Context-dependency**

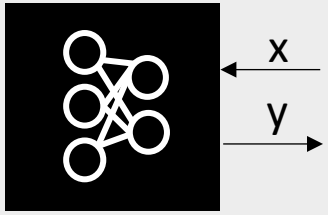


Privacy Acceptable?

Single Count Query

Visualization inspired by [Nanayakkara PETS'20]

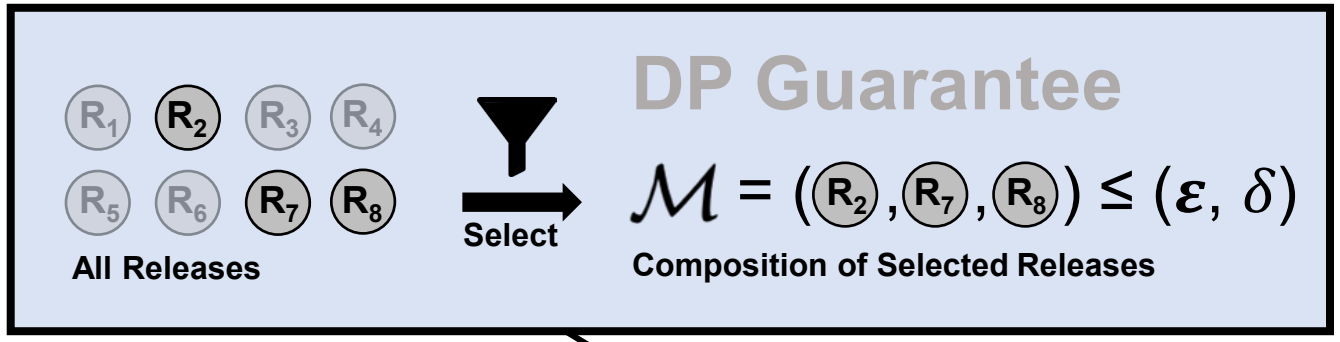
ML model (Blackbox access)

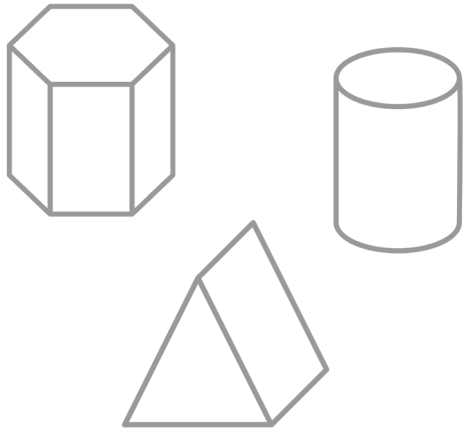


Blackbox ML: Empirical privacy auditing indicates a gap between theoretical DP bounds and actual attack success rates, potentially allowing larger ε.

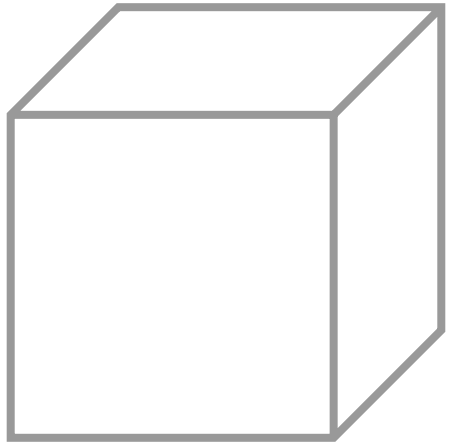
[Nasr S&P'21, Usenix Security'23, ICLR'25]

Our Approach

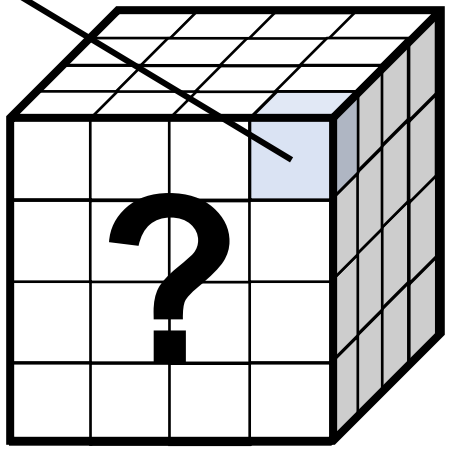




Multiple Isolated Guarantees



One Single Global Guarantee

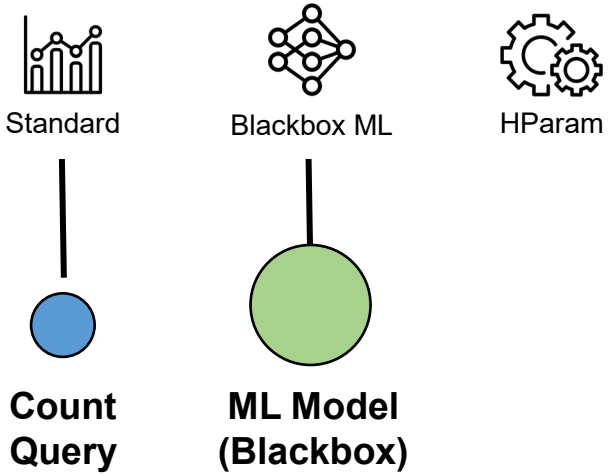


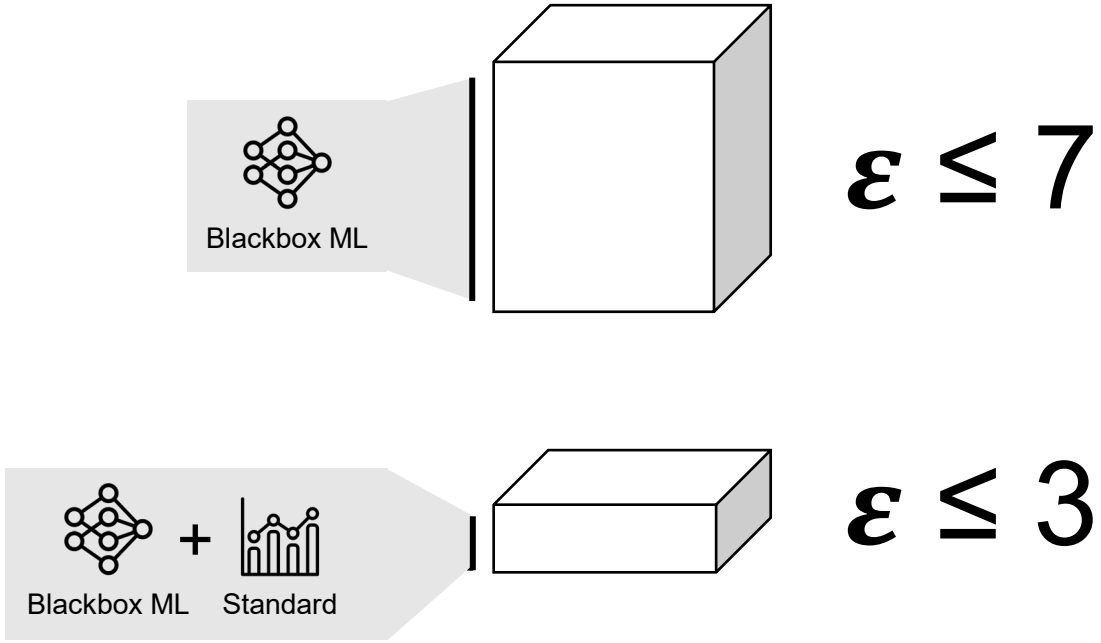
Multiple Complementing Guarantees

Dimension 1: **Multiple Contexts**

Adjust the privacy budget based on the context

Example Contexts





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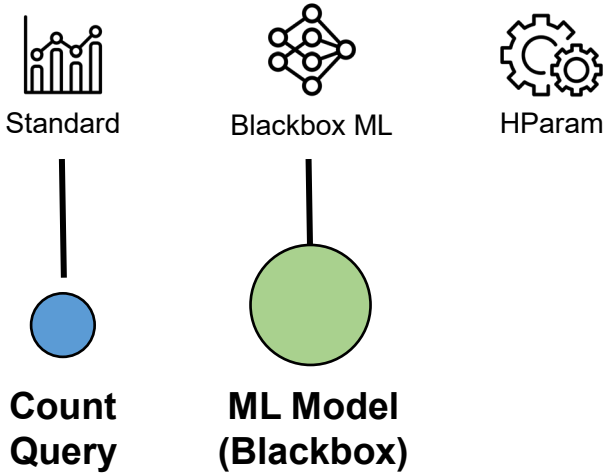
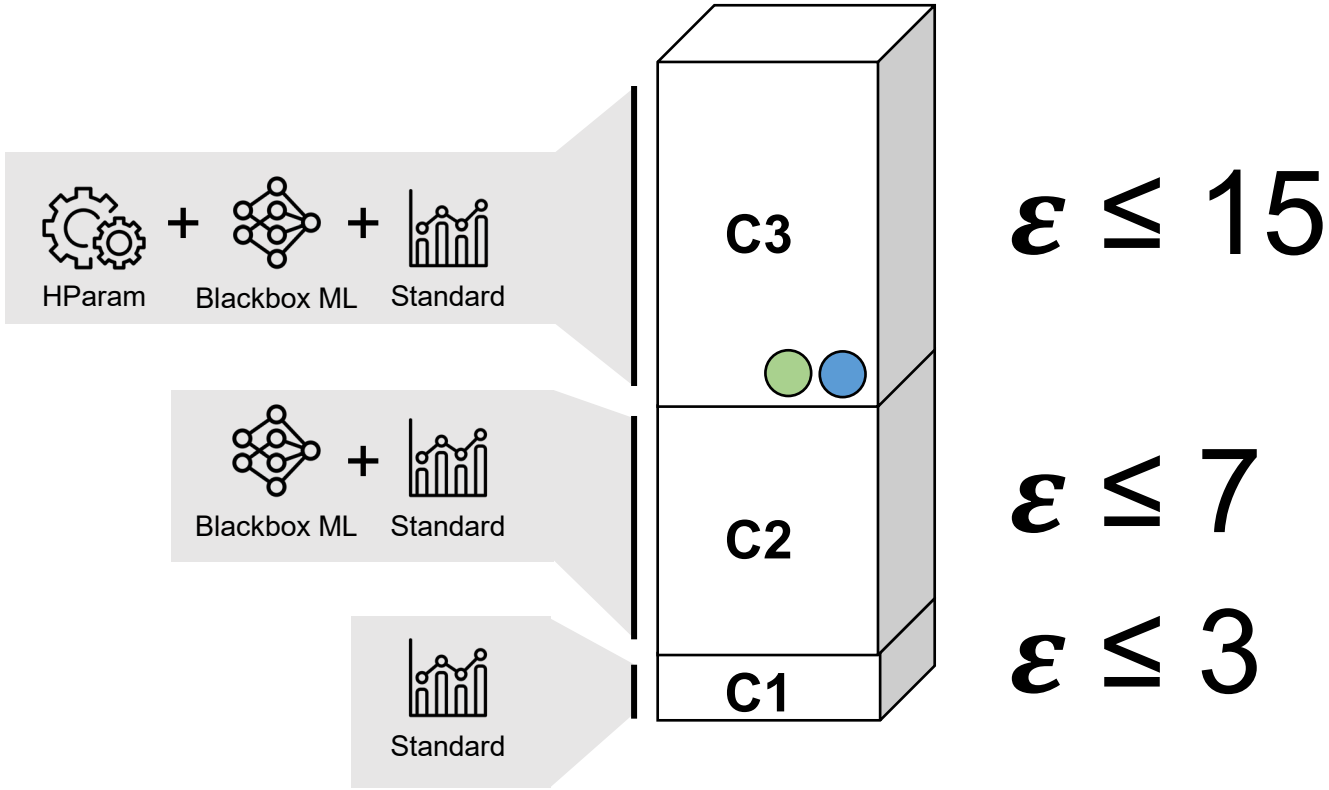




Dimension 2: **Multiple Scopes**

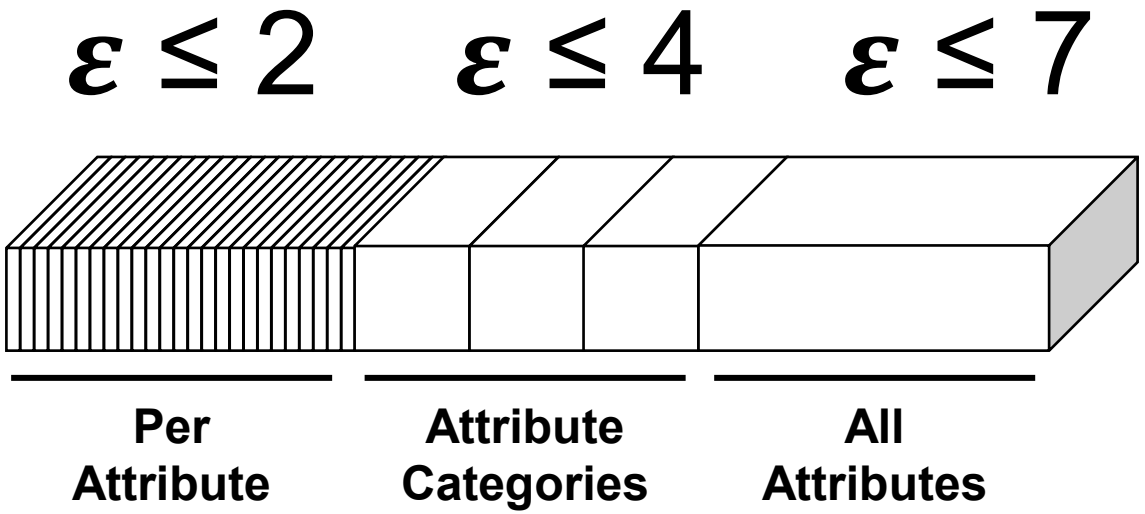
Define scopes over the large collection of data

Example Data

Relational Data

Documents

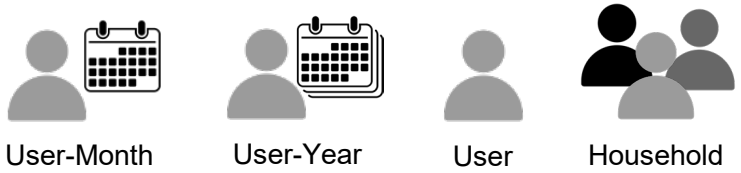
Image Dataset

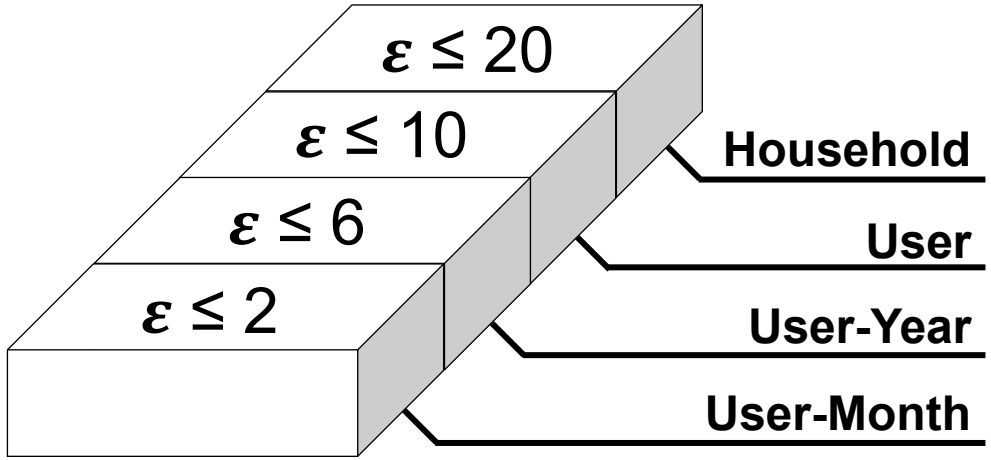


Dimension 3: **Multiple Privacy Units**

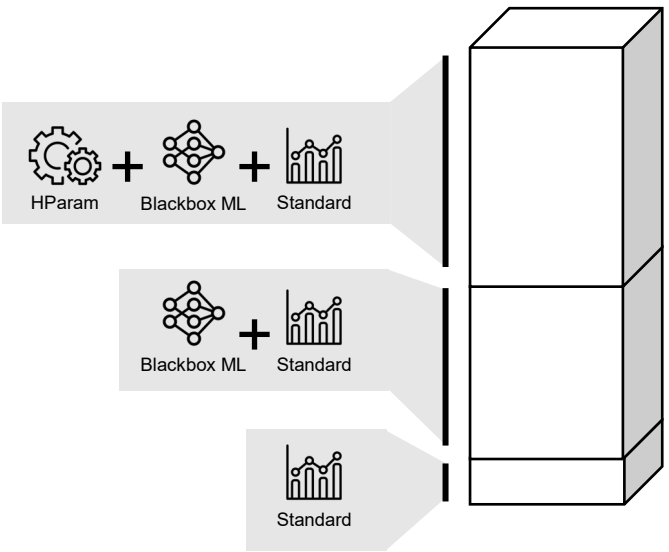
Support for multiple privacy units

Example Privacy Units



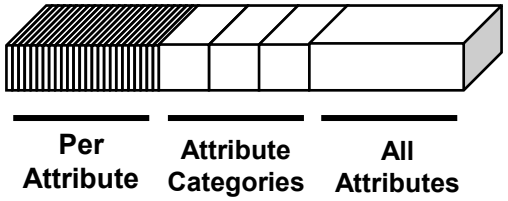


Multiple Complementing Guarantees



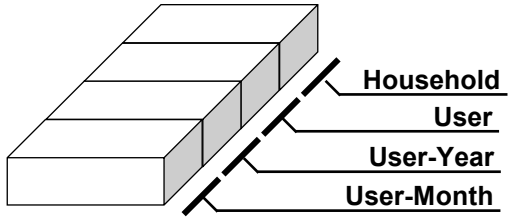
Multiple Contexts

Dimension 1



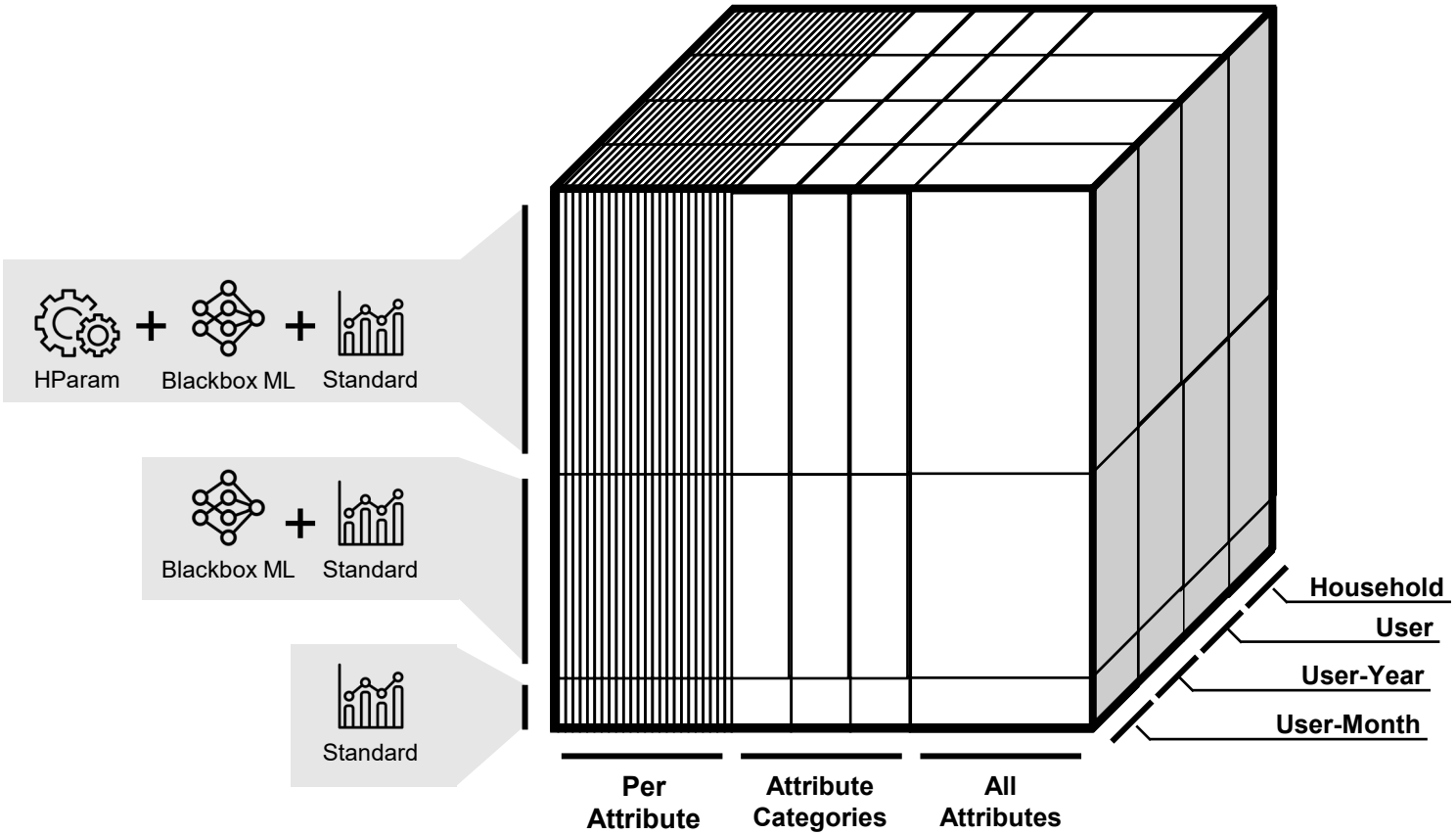
Multiple Scopes

Dimension 2

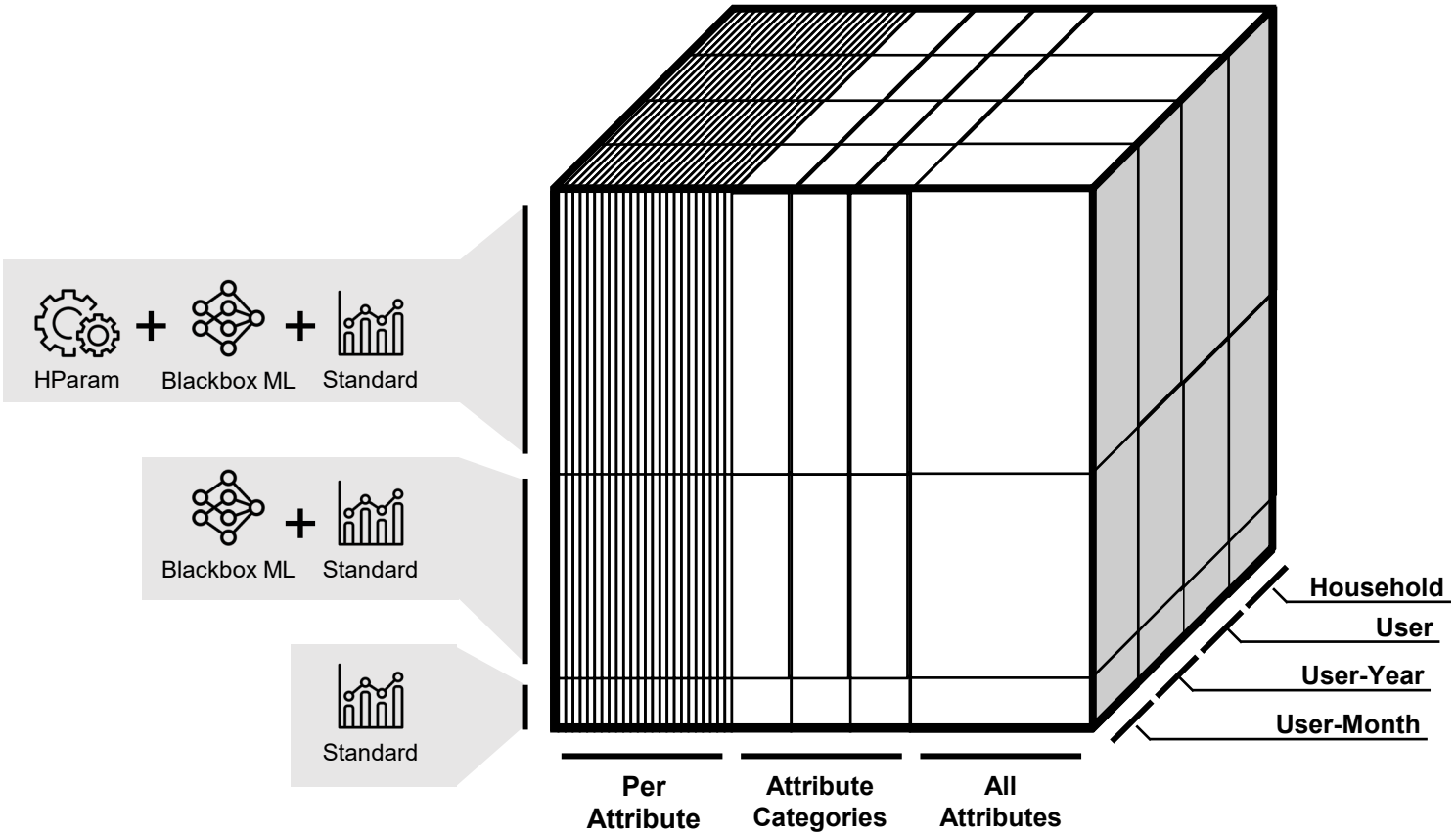


Multiple Privacy Units

Dimension 3



Multiple Contexts **Multiple Scopes** **Multiple Privacy Units**

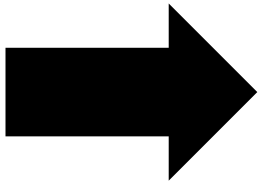


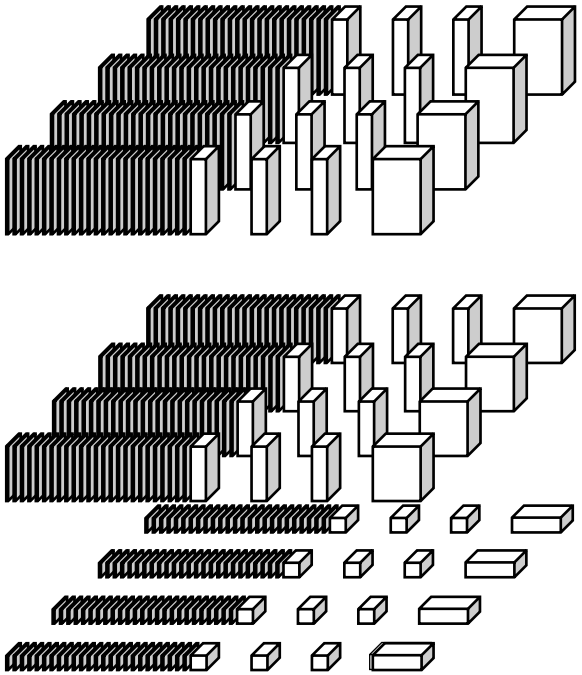
Multiple Contexts **Multiple Scopes** **Multiple Privacy Units**

DP Policy Language

Deriving the large rule set by a concise policy language

Policy Set

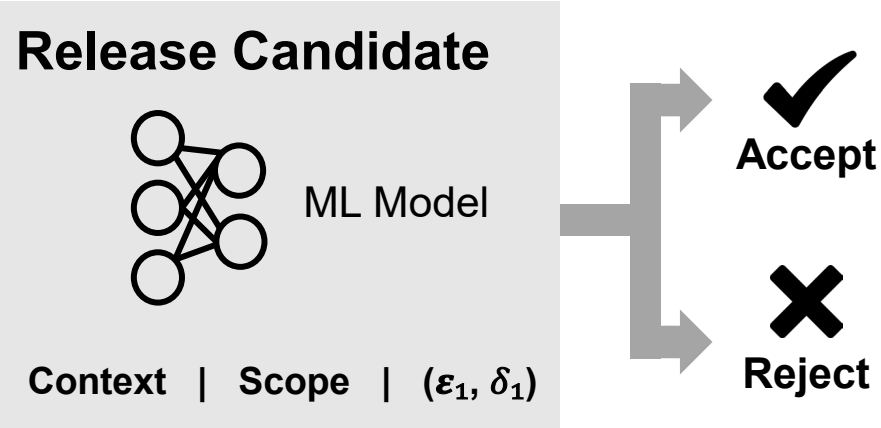


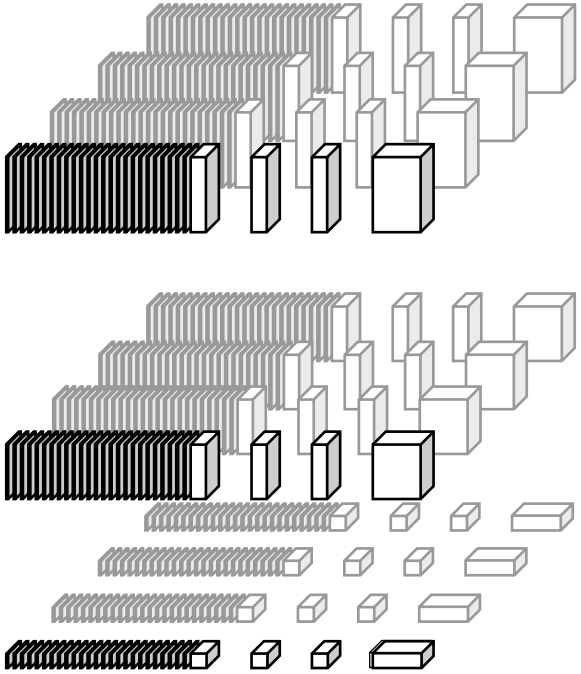


Problem: Large Rule Set

Policy Enforcement

How to find the relevant rules? Do we need to check all?



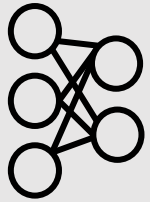


Large Rule Set

Policy Enforcement

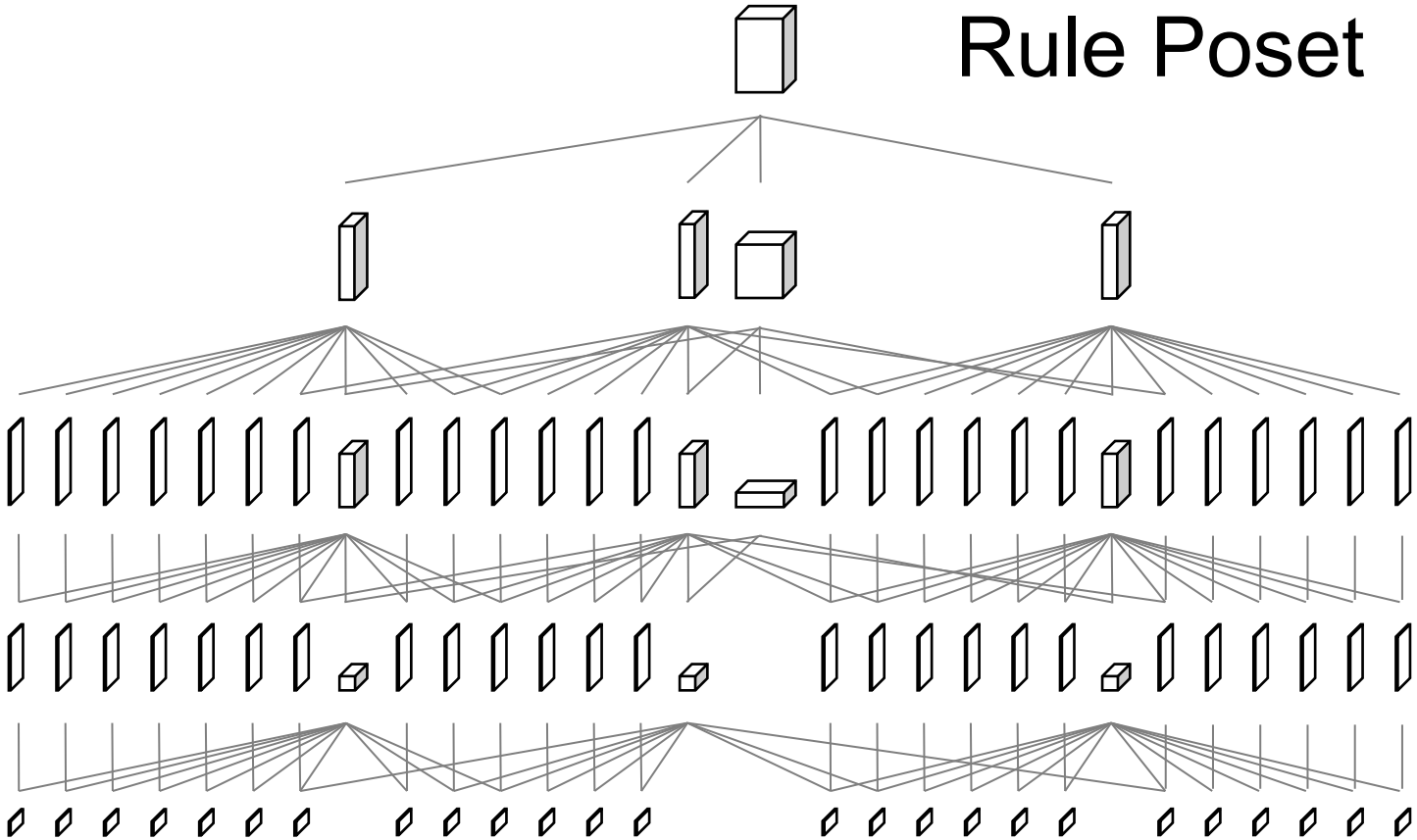
How to find the relevant rules? Do we need to check all?

Release Candidate



ML Model

Context | Scope | $(\varepsilon_1, \delta_1)$



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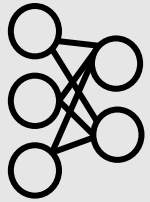

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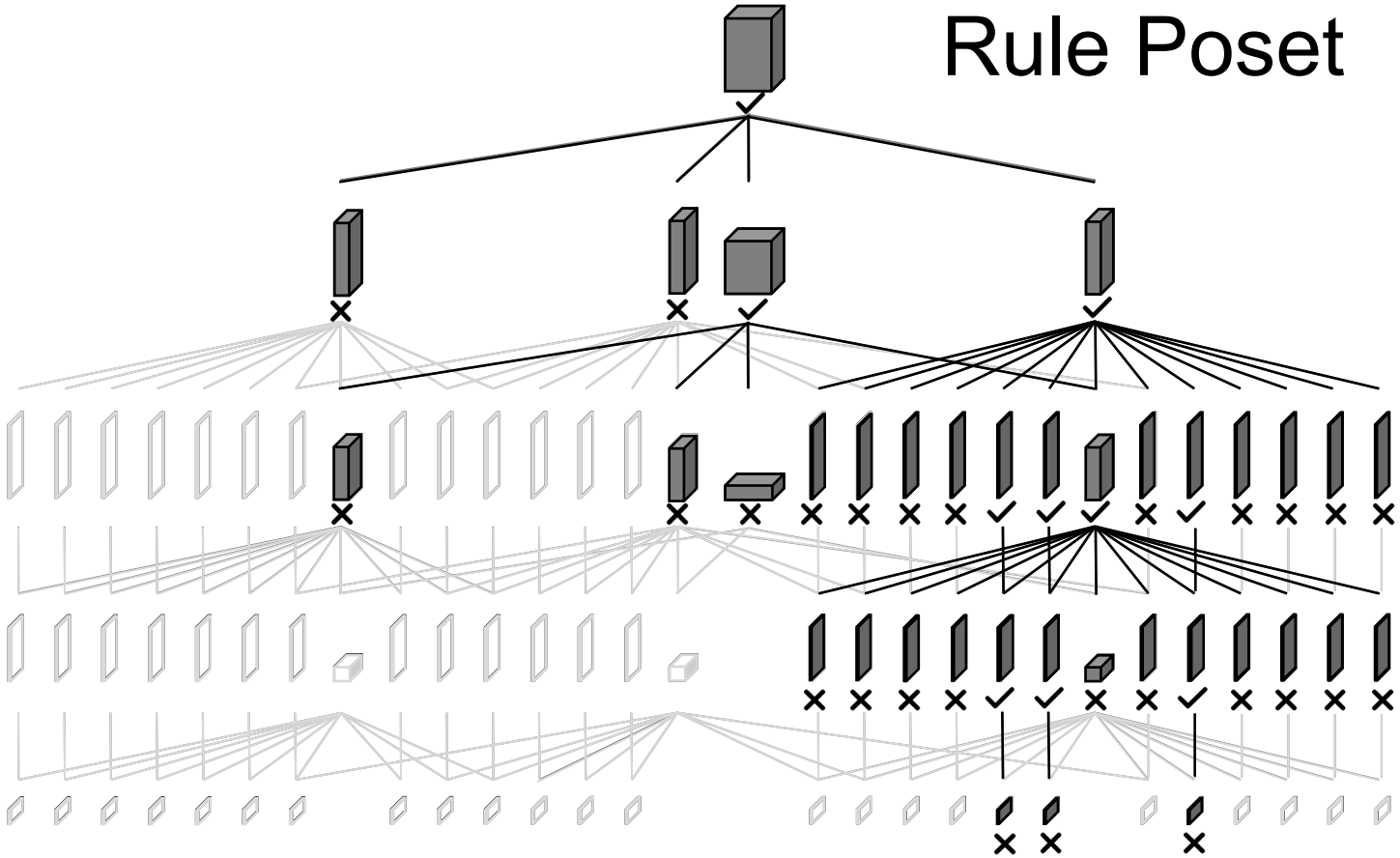
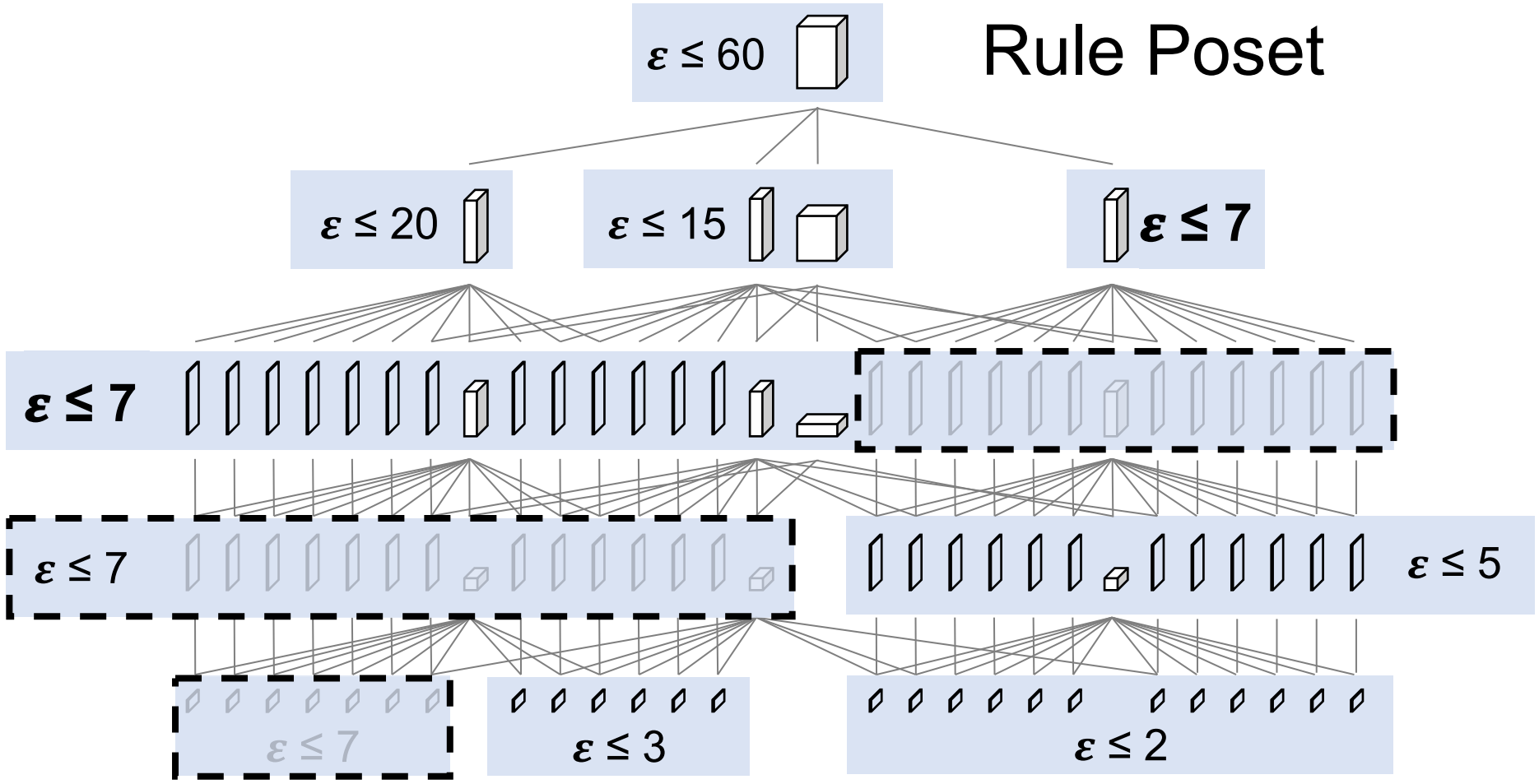


Rule Set Optimization

Are all the rules required?



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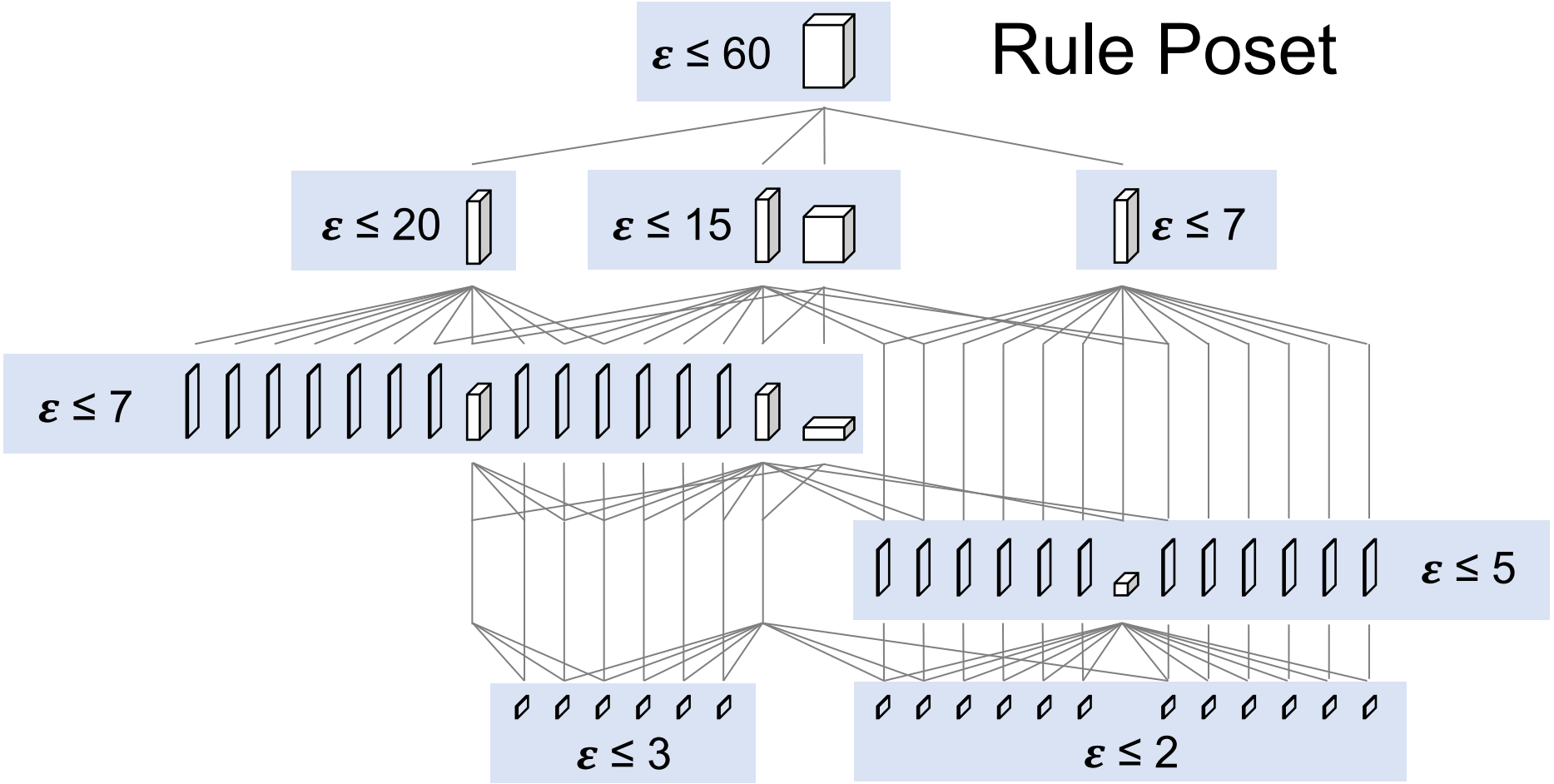
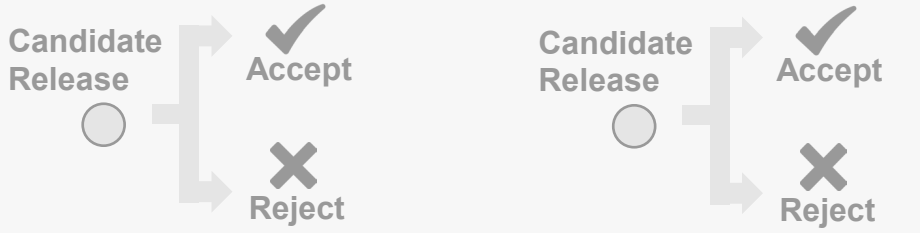


System Integration

DP Libraries

Examples: Tumult Analytics, OpenDP

1. Set Privacy Budget
2. Check the remaining budget to accept / reject the release candidate.



DP Management Systems

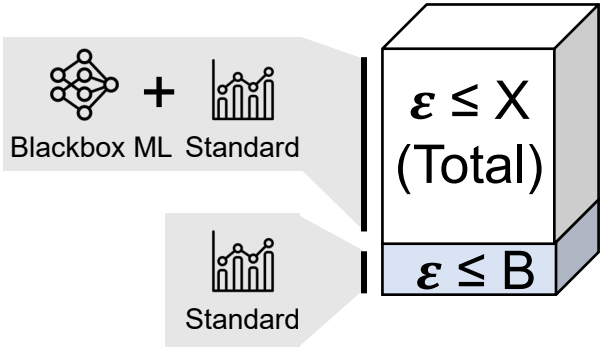
Examples: PrivateKube [Luo et al. OSDI'21] Cohere [Küchler et al. S&P'24]

1. Set Privacy Budget
2. Find the best allocation of candidate releases subject to the available privacy budget.

Evaluation

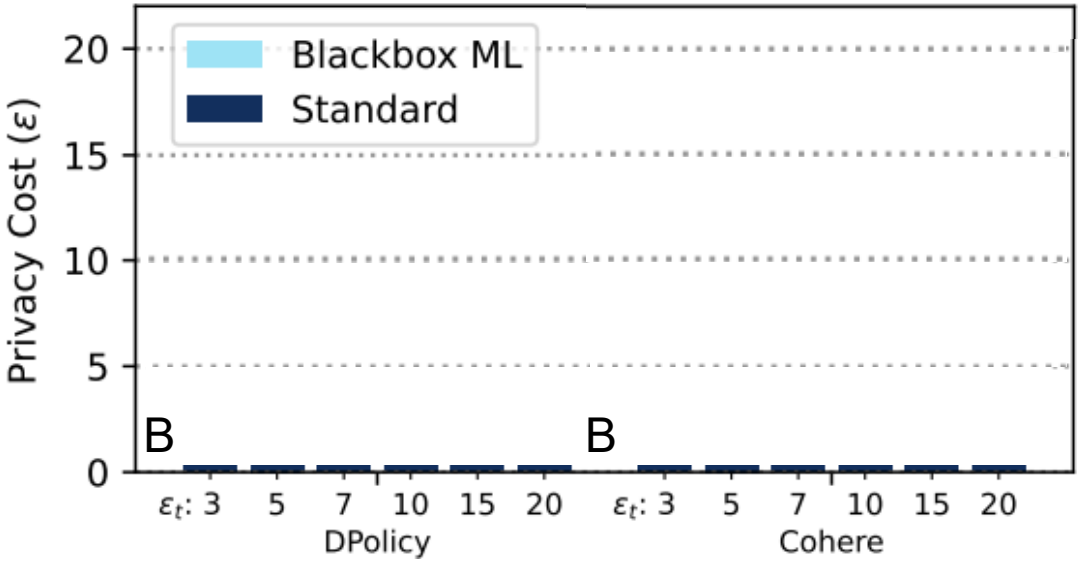
Cohere Workload

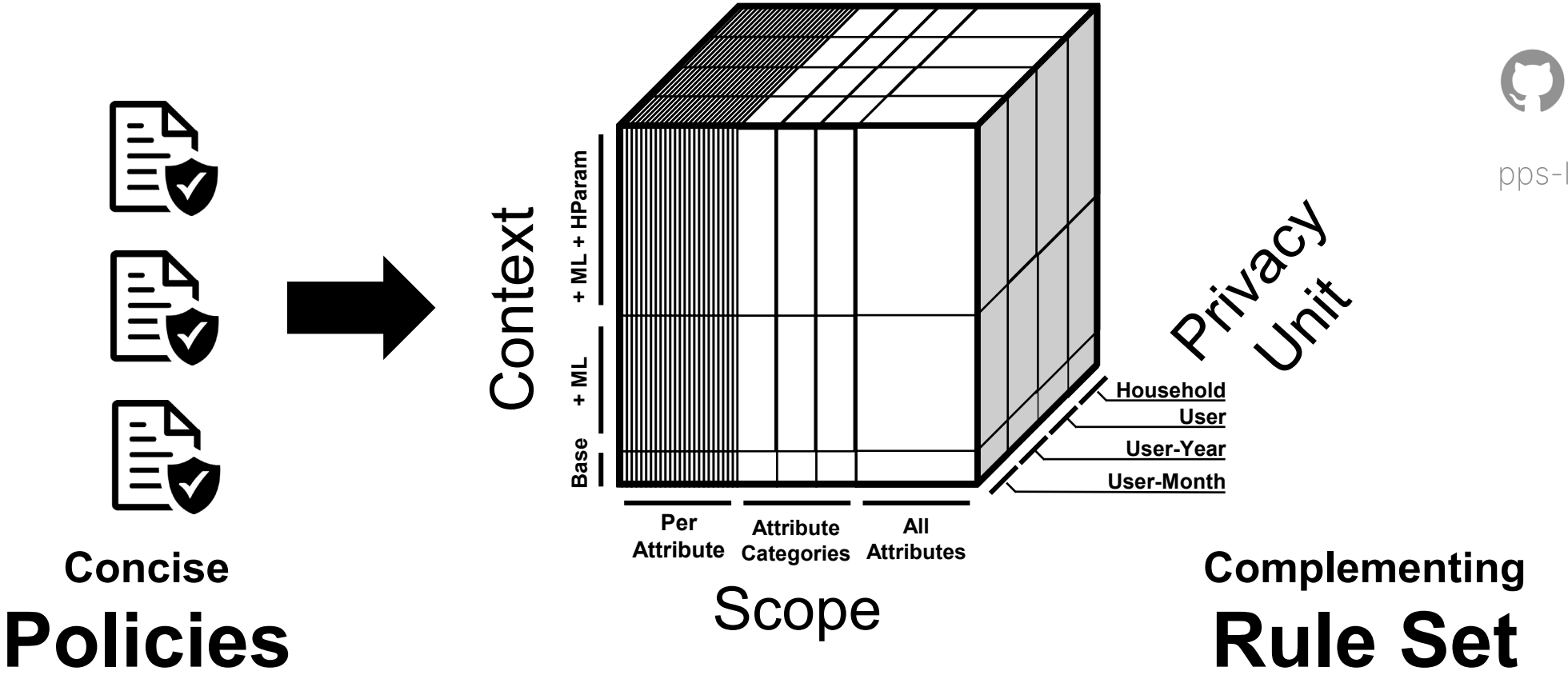
[Küchler et al. S&P'24]



DPolicy (ours)

Cohere





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