# Towards A Taxonomy of Privacy for Digital Currencies in Regulated Environments

**Privacy and Public Policy Conference 2026**

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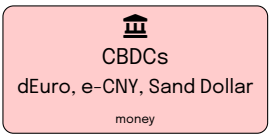
# Motivation

# Recent Evolution of Digital Money

## From cryptocurrencies to stablecoins and CBDCs






- **Cryptocurrencies:** Sparked a new area of financial technologies (distributed ledgers, decentralized cryptographic protocols) [Nak08; Com15]
- **Stablecoins:** Draw on cryptocurrency advances, aim for stability [DU23; LSSS20]
- **CBDCs:** Central banks increasingly explore novel financial rails [DKM24]

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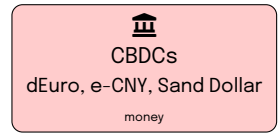


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|---|---|---|
| Bitcoin, Ethereum | USDC, Tether, ~~Libra/Diem~~ | dEuro, e-CNY, Sand Dollar |
| unbacked private money | backed private money | money |

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| | | |
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| Either transparent or blocked | Oftentimes lack privacy | Should be private and regulated |

# The Privacy-Regulation Dilemma

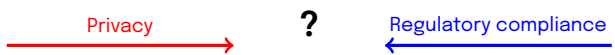
### Citizens Want

- Privacy comparable to cash
- Protection from surveillance
- Financial autonomy
- Price stability

### Regulators Want

- AML/CTF compliance
- Tax enforcement
- Investigative capabilities
- Financial oversight

**Central tension:** How to balance privacy and regulatory compliance?



# Current Approaches Fall Short

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**Binary treatment:** Privacy fully provided or entirely absent
**Limitation:** Doesn't reflect institutional settings

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**What is needed:** A framework that treats privacy as configurable

# Our Contribution

**A multidimensional taxonomy**

## Privacy as a configurable space

**Five independent dimensions:**

- **Who:** Identity (anonymous → identified)
- **What:** Information protected (amounts, links, origins)
- **How:** Disclosure control (user consent, protocol, institutional)
- **Why:** Legal basis (statutory, contractual, policy)
- **Where:** Disclosure scope (participants, intermediaries, regulators, public)

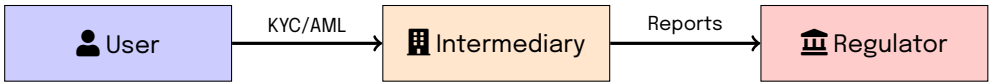
*Each dimension can be independently reasoned about, implemented, and governed*

## Before diving into the taxonomy details...

Let’s establish some background concepts

# Regulatory Approach: Intermediary Oversight

**Traditional banking model extended to cryptocurrencies**




- **Traditional finance:** Banks as choke points for monitoring
- **Cryptocurrency regulation:** VASPs as financial intermediaries [OBC23]
- **Key regulations:** MiCAR (EU), TFR, (FATF Travel Rule) [Fin25]
- **Limitation:** Centralizes control, power asymmetry [KPPO24]

# Technical Privacy Properties

**Four core dimensions of privacy in digital currencies**

## Anonymity (Network-level)

Prevent association between transactions and real-world identity

- Cryptographic addresses
- Tor, Dandelion
- Pseudonymity $\neq$ anonymity

## Unlinkability (Application-level)

Prevent correlation of multiple transactions to same user

- Address rotation
- Stealth addressing
- CoinJoin, Tornado Cash

## Confidentiality (Application-level)

Hide transaction amounts and balances

- Homomorphic commitments
- Range proofs

## Untraceability (Application-level)

Hide which output a transaction spends

- Ring signatures
- Zero-knowledge proofs

# Taxonomy

# Recall: Our Five Dimensions

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*Now let's explore each dimension in detail*

# Dimension 1: Who (Identity)

**Real-world identity of transacting parties**

**Level 1: Anonymity:** No connection to real-world identity *(Monero [KAN20] over Tor)*

**Level 2: Pseudonymity:** Persistent identifiers, volatile linkage *(Bitcoin [Nak08] addresses)*

**Level 3: Legitimacy:** Anonymous credentials, no direct identity *(BBS+ credentials [BBS04])*

**Level 4: Identified:** Full KYC, identity bound to transactions *(Traditional banking, China's DCEP [Peo21])*

## Observation

Level 1 systems face regulatory hurdles, Level 4 systems meet oversight requirements: trade-off between privacy and accountability

# Dimension 2: What (Transactional Data)

**Layered hierarchy of information protection**

**Level 1: All properties protected:** Confidentiality + unlinkability + untraceability *(Monero [KAN20], Zcash shielded [Ben+14])*

**Level 2: One property violated** *(Early CryptoNote [Sab13]: amounts visible)*

**Level 3: Two properties violated** *(Mimblewimble [Jed16]: some linkability and traceability)*

**Level 4: All information visible,** fully transparent *(Bitcoin [Nak08], traditional banking)*

## Observation

Privacy properties are not binary switches: they form a spectrum that can be calibrated based on regulatory needs and user requirements

# Dimension 3: How (Access Control)

**Governance framework and technical infrastructure**

**Level 1: No disclosure:** Data known only to participants (offline eCash)

**Level 2: User action required:** View keys, selective disclosure (Monero, Zcash [Ben+14])

**Level 3: Stakeholder cooperation:** Banks + regulators collaborate

**Level 4: Full disclosure:** Data accessible by default (Bitcoin, traditional banking)

## Observation

Fundamental design choice: extent to which users retain control over their data, from user autonomy (Level 1-2) to institutional oversight (Level 3-4)

# Dimensions 4 & 5: Why & Where

**Regulatory basis and disclosure scope**

### Why: Regulatory Basis

1. **Legal basis**
   Statutory law, constitutional principles
   *Example: Digital Euro legislation*
2. **Contractual basis**
   Private agreements
   *Example: Permissioned blockchains*
3. **Policy-based**
   Industry standards, compliance frameworks
4. **No normative basis**
   Unrestricted access
   *Example: Bitcoin (technical design)*

### Where: Disclosure Scope

- **Transacting parties**
  Personal financial management
- **Public visibility**
  Anyone can access
  *Example: Bitcoin blockchain*
- **Intermediary access**
  Banks, PSPs, VASPs
  Regulatory compliance role
- **Authority access**
  Regulators, tax authorities
  Legal frameworks (warrants, thresholds)

# Privacy Configurations

# Conditional Disclosure: Privacy Budgets

**Privacy by default with threshold-based disclosure**

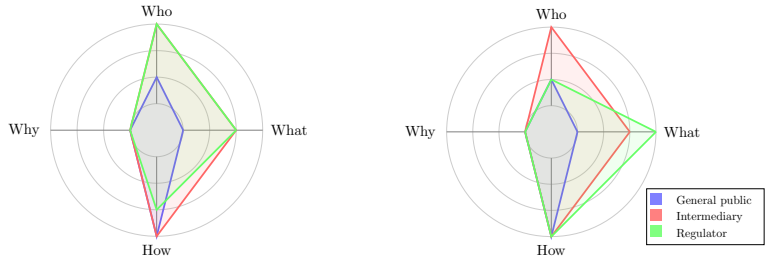


Figure: Below threshold (left): full privacy. Above threshold (right): regulatory disclosure

- **Systems:** PRCash [WKCC19], UTT [Tom+22]
- **Mechanism:** Anonymous credentials with embedded budgets
- **Below budget:** Zero-knowledge proofs, full privacy
- **Above budget:** Transaction details encrypted to regulator

# Mediated Privacy: Threshold Authorities

**Distributed disclosure authority**

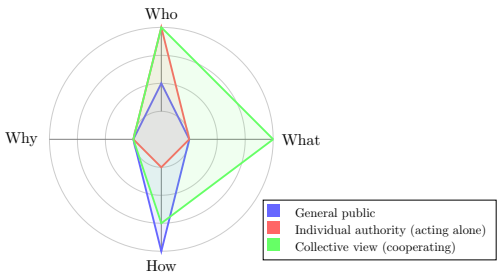


Figure: $(t, n)$ threshold: requires $t$ of $n$ authorities to cooperate

**Mechanism:**

- Decryption key split into $n$ shares
- Any $t$ shares reconstruct key
- Fewer than $t$ reveals nothing

**Benefits:**

- No single actor has unilateral power
- Prevents individual misuse
- Requires coordination for disclosure
- *Examples:* PEReDi [KKS22], UTT [Tom+22]

# Summary

# Key Insights

## Insight 1: Privacy as a tunable configuration space

Binary on/off privacy models fail to address regulatory nuance. Instead, we model privacy as a multi-dimensional **configuration space** with five independent, tunable axes - each adjustable to align with specific compliance, functionality, or risk requirements.

# Key Insights

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Binary on/off privacy models fail to address regulatory nuance. Instead, we model privacy as a multi-dimensional **configuration space** with five independent, tunable axes - each adjustable to align with specific compliance, functionality, or risk requirements.

## Insight 2: Selective configurations enable compliance with minimal surveillance

Regulatory compliance does *not* require pervasive transaction tracing. AML/CTF obligations typically demand visibility into amounts and counterparties; not complete historical linkage. **Carefully chosen configurations** can deliver strong privacy while satisfying these targeted requirements.

# Challenged Presumptions

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**Reality:** Effective oversight can be implemented at key interaction points or by embedding accountability mechanisms directly into protocols.

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**Reality:** Conditional disclosure, mediated access controls, and tunable transparency thresholds allow meaningful optimisation across both privacy and regulatory objectives.

## ✗ Presumption 3: Meeting legal requirements is precluded by technical infeasibility

**Reality:** Proportionality and purpose limitation can be enforced natively within cryptographic protocols, enabling **compliance-by-design** systems.

# Conclusion

## Achieving regulated privacy is a design challenge

**By treating privacy as multidimensional and configurable:**

- Systems can better safeguard user interests
- While simultaneously fulfilling regulatory requirements
- Often without forcing a trade-off between the two
- Instead, integrating both through careful cryptographic design

# Thank you for your attention!

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# Asymmetric Privacy: Sender vs. Receiver

**Chaumian eCash and Tourbillon project [BIS23]**

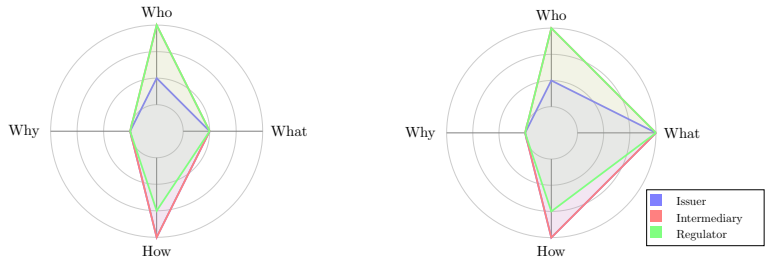


Figure: Sender (left) enjoys untraceability and unlinkability. Receiver (right) has reduced protections

- **Blind signatures** unlink withdrawals from spending
- **Sender:** Strong protection (Level 2 on *What*)
- **Receiver:** Must present coins for deposit (Level 3 on *What*)
- **Result:** Compliance monitoring at receipt points

# Targeted Exposure: View Keys

**Retrospective investigation without blanket surveillance**

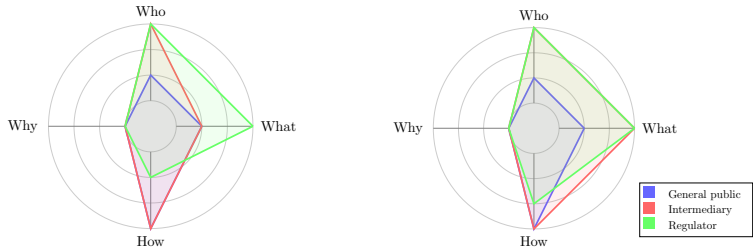


Figure: User cooperation (left) vs. intermediary control (right)

- **Two keypairs:** Spend key (transfer funds) + view key (decrypt values)
- **Governance model 1:** Users hand over view keys under legal mandate
- **Governance model 2:** Intermediaries obtain view keys during KYC
- **Trade-off:** User autonomy vs. regulatory enforceability

# Asymmetric Privacy: Offline vs. Online

**Context-dependent privacy guarantees [CMGS22; SE24]**

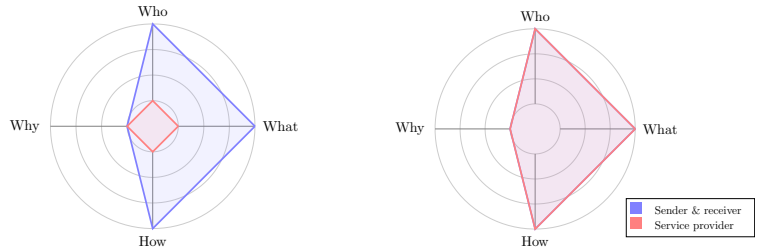


Figure: Offline (left) provides full anonymity. Online (right) requires identification

- **Offline:** Complete anonymity, no institutional disclosure
- **Online:** Full identification, automatic processing
- **Settlement:** Users reconnect, lose anonymity but retain transaction untraceability
- **Physical proximity** limits scale vs. global online networks

# Mediated Privacy: Split Visibility

## Compartmentalized institutional access

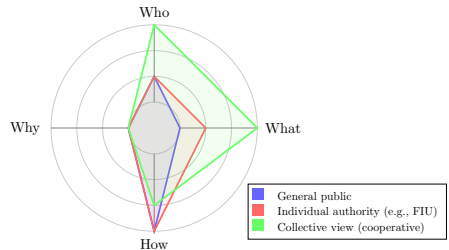


Figure: Different authorities see different fragments; no single complete view

- **FIU:** Observes pseudonymous flows, AML compliance proofs (no identities)
- **IVA:** Maintains KYC mappings (no transaction amounts)
- **Tax authority:** Receives aggregate values (no individual transfers)
- **Result:** Institutional checks and balances, prevents complete surveillance

# Regulating Public Ledgers

## Privacy mechanisms in permissionless systems

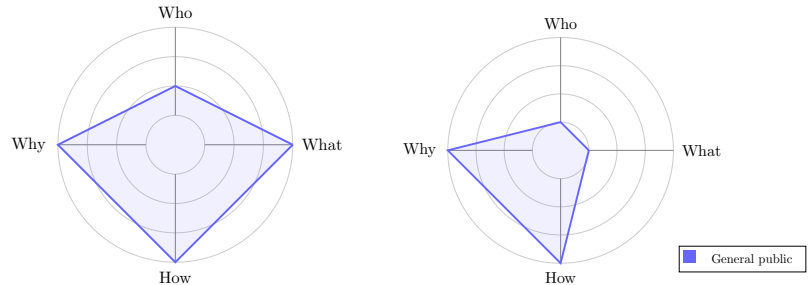


Figure: Bitcoin [Nak08] (left): transparent. Monero [KAN20] (right): privacy-preserving by default

- **Challenge:** No centralized control, prioritize censorship resistance
- **Approaches:** Regulated mixers [Max13] (KYC at access points), compliance proofs for Tornado Cash [PSS19; BINSS23], view key requirements for privacy coins