Privacy Pass: Redemption Contexts

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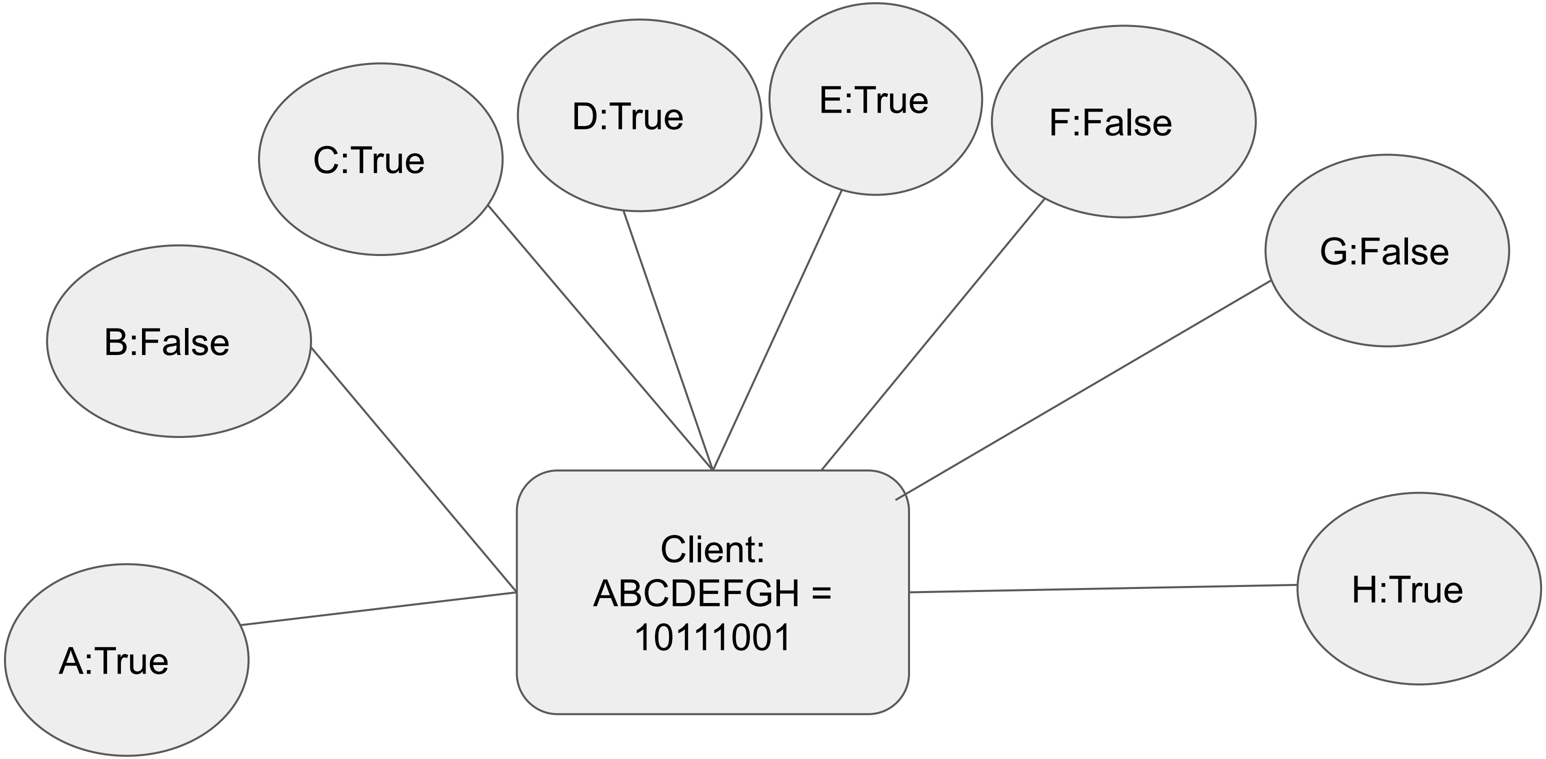
What are Contexts

- Places with shared anonymity/privacy properties
- Privacy Pass (Current)
  - 1 Global Context
  - Client in a single anonymity set based on all the redemptions in performs
- HTTP
  - Shared Contexts
  - Site-level information boundaries
  - Top-Level Sites (First-Party)
  - Mostly
    - Cross-Site Information Transfer (3P Cookies)
- Devices
  - Shared Contexts
  - Applications
  - Mostly
    - Device Identifiers/Fingerprints

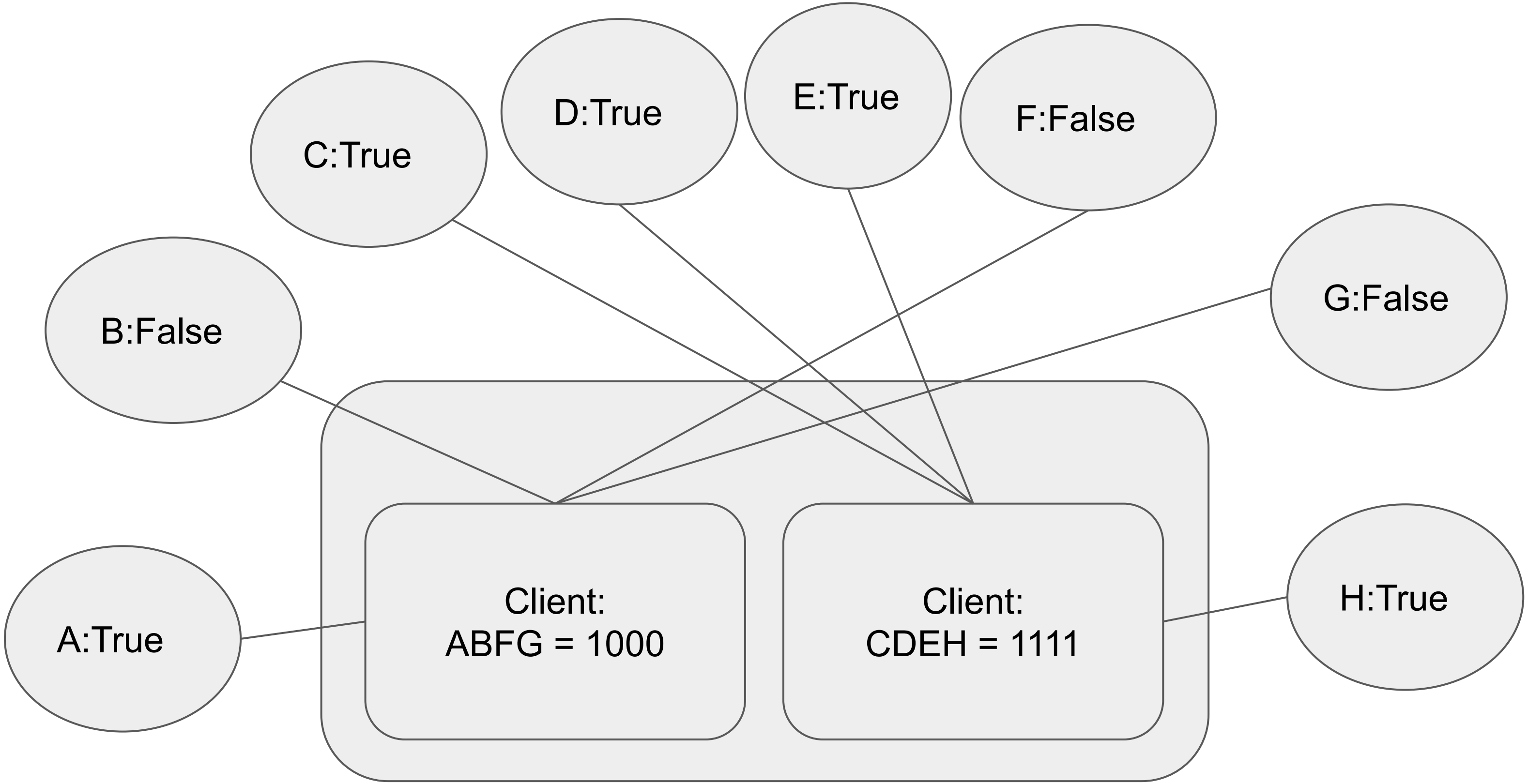
Global Redemption Context



Global Redemption Context

- N Issuers in the global ecosystem
- 2^N anonymity sets
- (2+M)^N anonymity sets with M additional metadata bits
- N < 10 total issuers to maintain anonymity sets of 5000 assuming 8B people with no additional metadata (beyond the inherent present/missing bit) and one epoch for key rotations (log2(8B/5000)-1)/2.

Sharded Redemption Context



Sharded Redemption Context

- N Issuers in the global ecosystem
- R Redemption attempts per context
  - Each redemption attempt has privacy implications
  - Where meaning of a pass may change over a period of time
- 2^R anonymity sets
- (2+M)^R anonymity sets with M additional metadata bits
- Target number of issuers is dependent on the size of the context’s population

Redemption Context Requirements

- Strong Privacy Boundary between Contexts
    - Privacy leakage from redemption in one context doesn’t affect another context
    - Separate anonymity sets/privacy calculations
    - Information about redemptions in one context don’t affect a different contact.
- Unjoinable
- Application Specific Challenges
    - Fingerprinting (Device, IP, etc)
    - Dealing with leakage between contexts (cross-site tracking, caching attacks, etc)

Protocol

```
# context - Self-contained context for a particular set of PrivacyPass operations.
# server - Identifier for a particular known PrivacyPass issuer/server
# info - info field from the Redeem method
Client.AttemptRedemption(context, server, info) {
  if (server in redemptionContexts[context]) {
    return Redemption(server, info)
  }
  if (redemptionContexts[context].length > REDEMPTION_LIMIT) {
    return False
  }

  redemptionContexts[context].add(server)

  if (store[server.id]) {
    return Redemption(server, info)
  }
  return False
}
```

Issuer Stickiness

- Since the presence/absence of a token splits the anonymity set, any attempt to check if tokens are available or redeem must count against the context limits. With T total issuers, R redemption attempts, at most K redemption successes:
    - R = 1, K = 1, 1 anonymity set based on first attempted issuer in the context.
    - K = 1, R = infinity, on average T/2 anonymity sets assuming a single issuer issued tokens to this client.
    - ~ min(2^R, T^K)
- Context commits to specific issuers or first R issuers requested are used.
- Stickiness Expiration
    - Never - Bad footgun.
    - Immediately - Results in attacks involving rapidly swapping through supported issuers
    - **Key Rotation** - privacy calculations overlapping with costs of a key rotation (most promising).
    - Data Lifetime - Linking to any other long-term data storage within the context.
    - Random Selection - Still splits the anonymity set, but less directly.

Open Questions

- Add protocol support for contexts vs leaving it purely application-layer
  - Latter would likely mean under PrivacyPass the anonymity set sizes would be tiny and privacy-problematic, and only solved as a result of the application-layer partitioning.
- Guidance in architecture for anonymity set/privacy math based on contexts vs global limits (#65)
- What requirements/discussion of underlying layer
  - unlinkability between issuance and redemption
  - generalized to unlinkability across contexts
- Managing issuer pinning
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