PROCHLO: Strong Privacy for Analytics in the Crowd

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Systems Analytics and Privacy

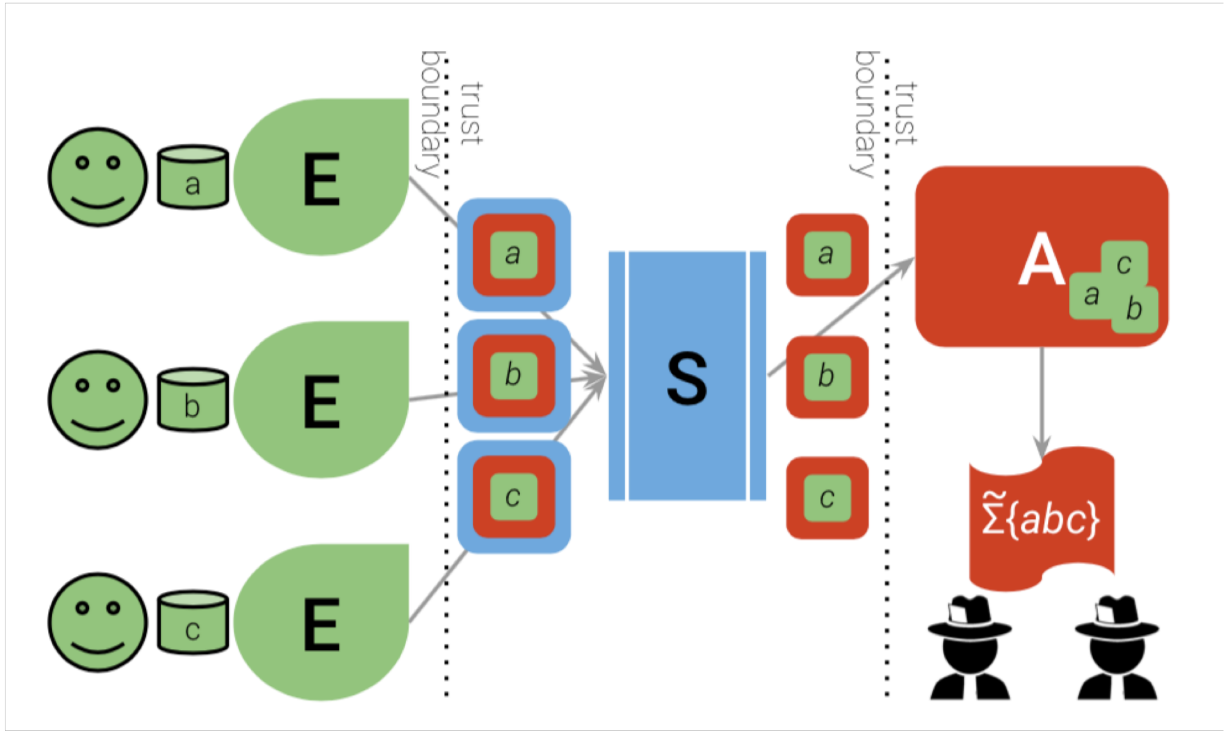
Monitor API usage on software platforms

How to do the analytics?

How to handle the private data carefully?

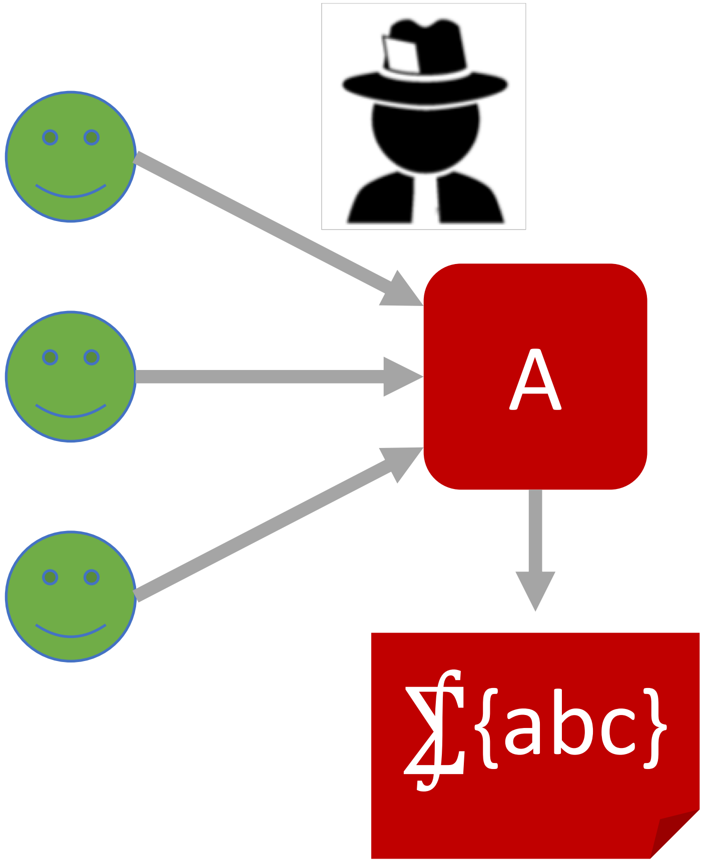
ESA Architecture and Prochlo Realization

- Perform such monitoring with
  - High utility
  - Strong privacy guarantees
- Encode, Shuffle, Analyze
  - Framework for monitoring
  - Privacy protection
  - Fit to software engineering
- Prochlo
  - A hardened ESA realization
  - SGX
  - Oblivious shuffling
  - Threshold crypto & blinding



Naïve API Monitoring

- What could go wrong?
- Uncommon API in an unpopular App
- At-least-K uses of an API
- Hard to get right!
  - Certain groups favor certain app features
  - IP address may reveal location
  - Etc.



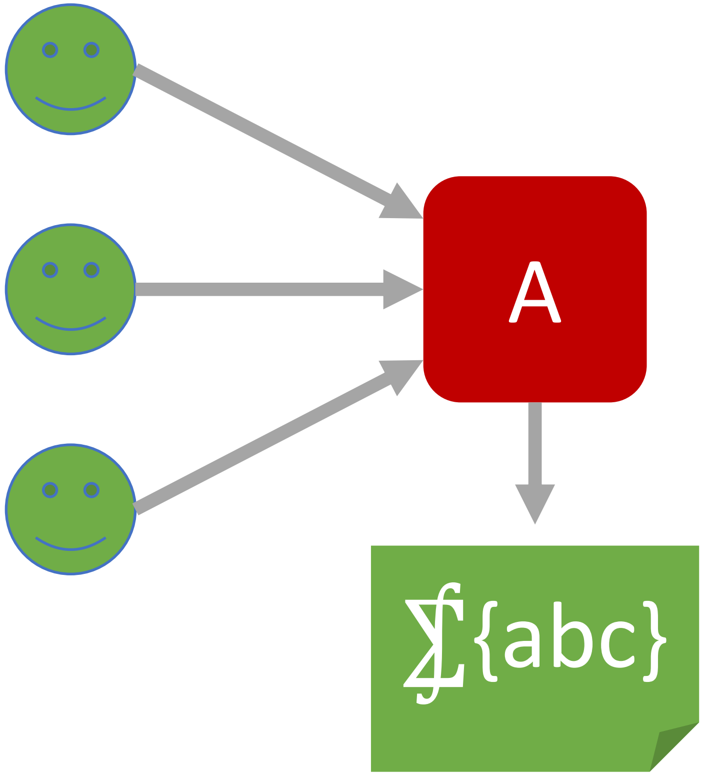
Differential-Privacy Data Analysis

- DP gives (ε, δ) upper-bound on privacy loss
- Holds for all questions & for all attackers priors

$$Pr[M(D) \in S] \leq \underline{e}^{\epsilon} Pr[M(D') \in S] + \underline{\delta}$$

Multiplicative upper bound

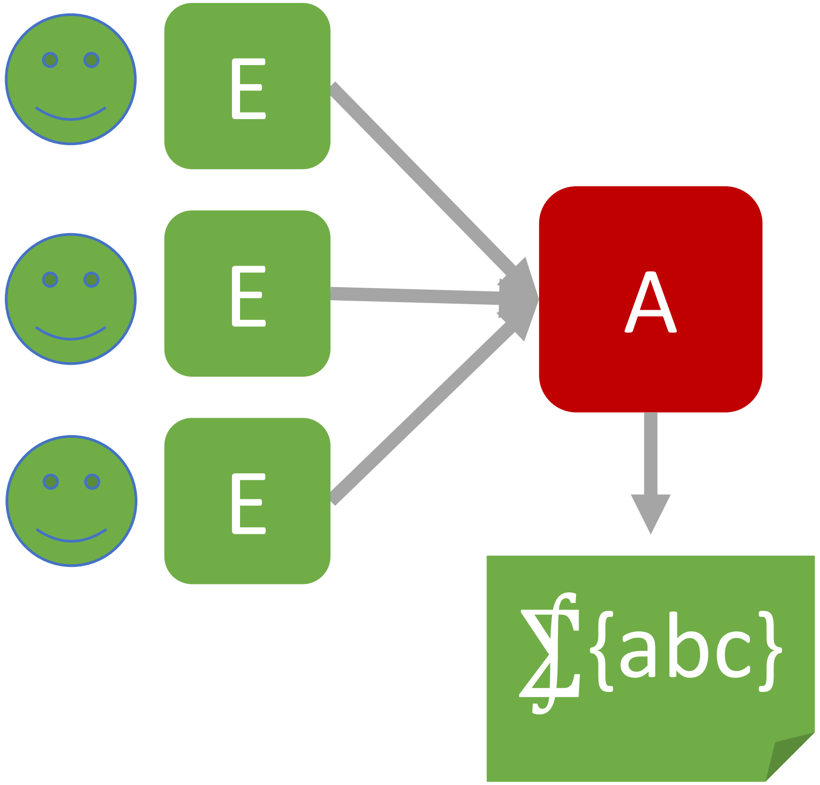
Very small failure rate



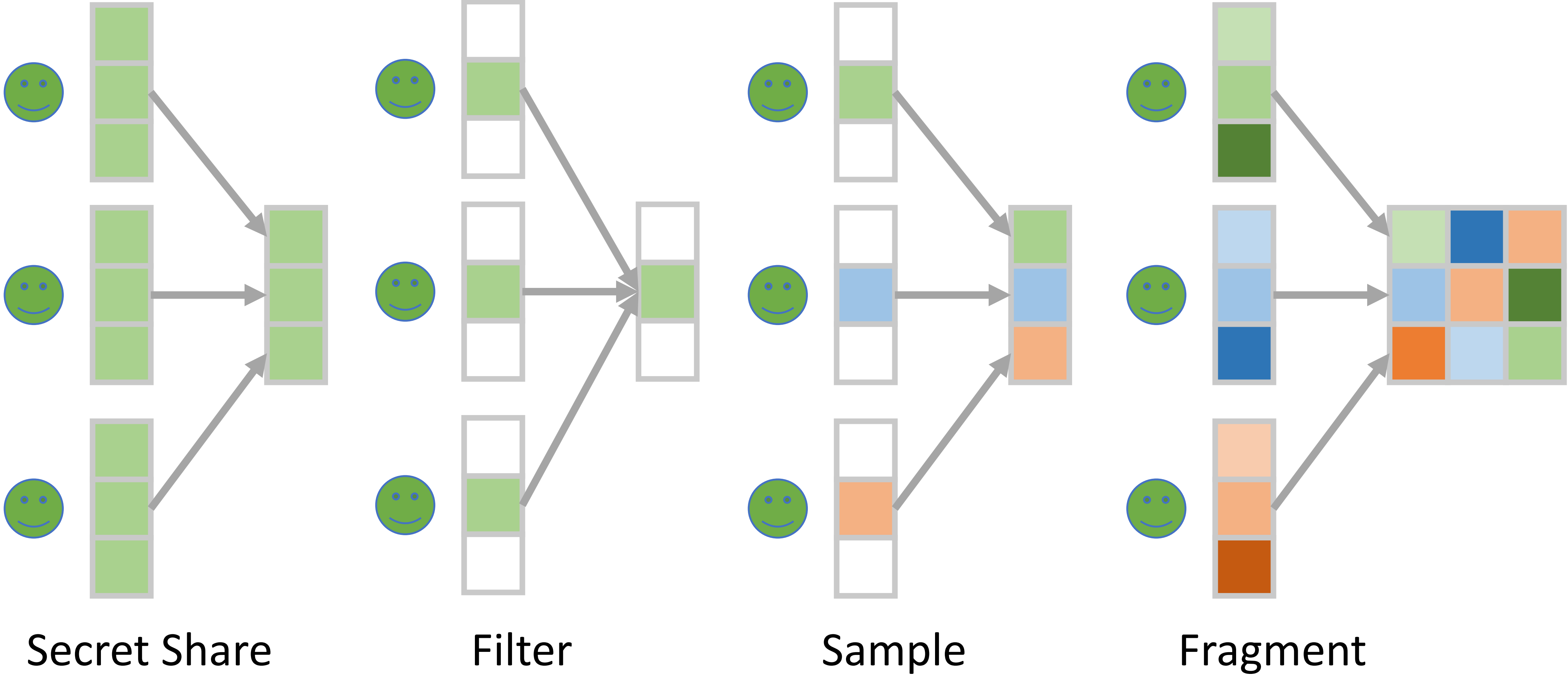
- Fundamental flaw with using database in DP
- Bad fit for software engineering
  - New algorithms and systems
  - Protect the databases forever

Randomization & Local DP

- Randomized response
- No central (hackable) DB of real, private user data
- Google's RAPPOR system
  - Software monitoring system for Chrome
  - Since 2014
  - Largest deployed differential private mechanism solution
  - Dozens of purposes, billions of randomized daily reports
- Limitations:
  - Only good for very popular things and very large datasets
  - Too statistical
  - Too much noise (grows as sqrt(#reports))

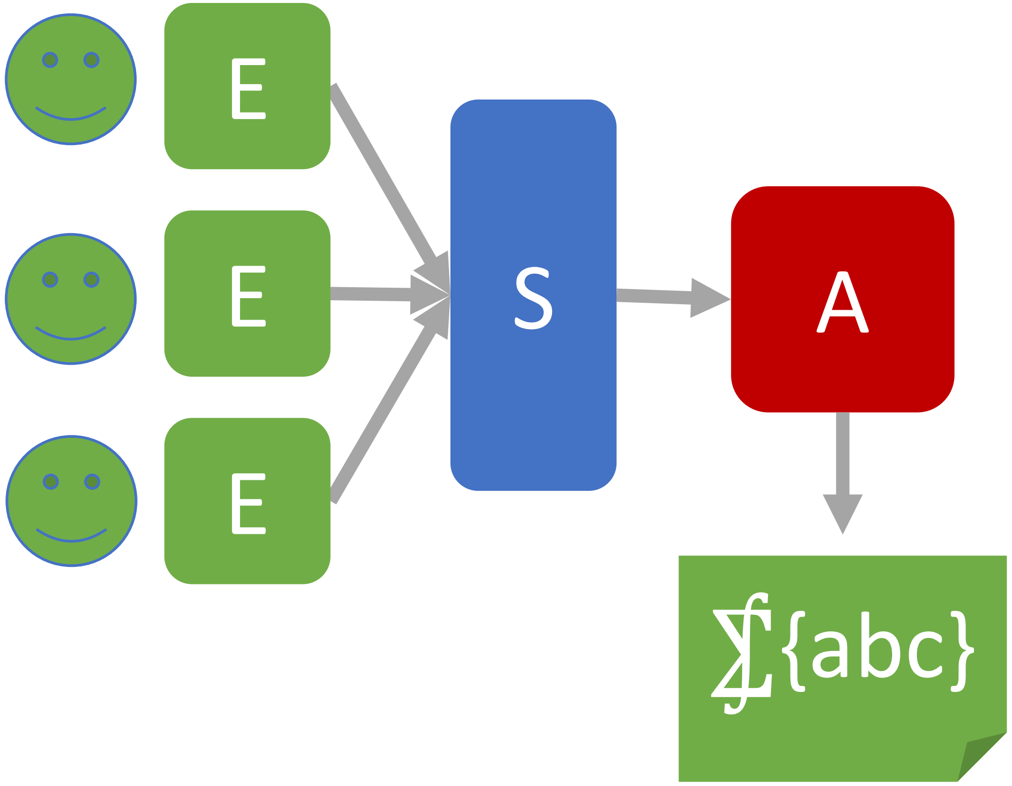


Encoding Fragments and Crowds

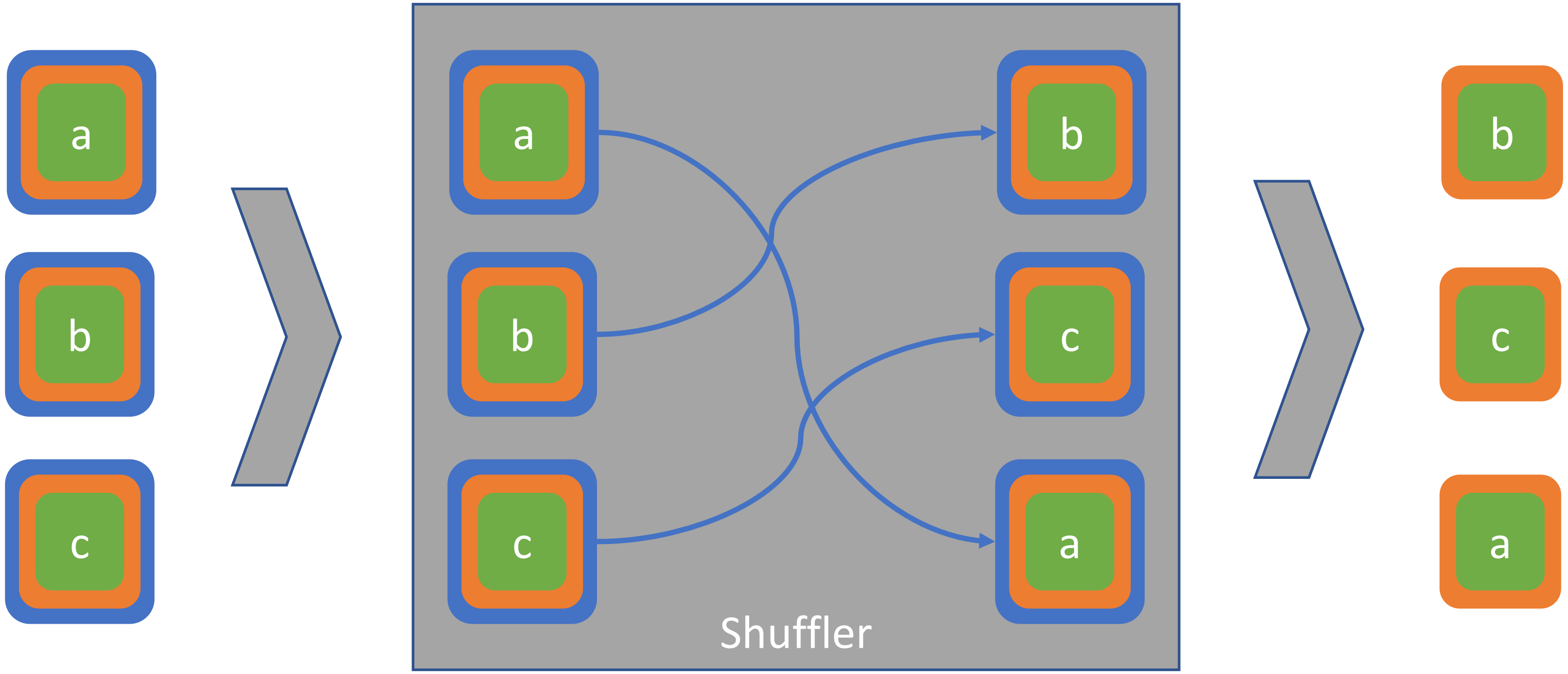


Anonymity, Batching and Shuffling

- Shuffling provides anonymity
  - Strips IP address & metadata
- Create big crowds
  - By delaying and batching
  - Per-day, in 100s of millions
- Randomly shuffle the reports
  - Break linkability between fragments
  - Hide ordering and timing information

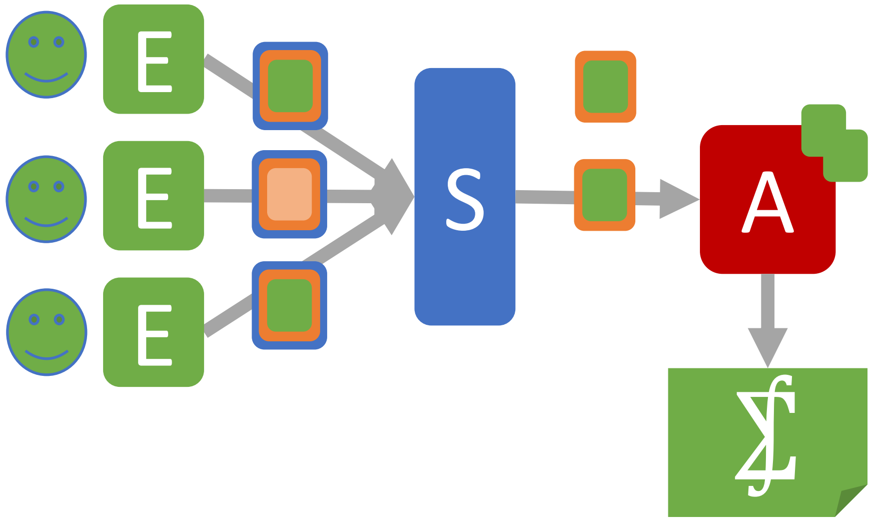


Shuffling and Nested Encryption

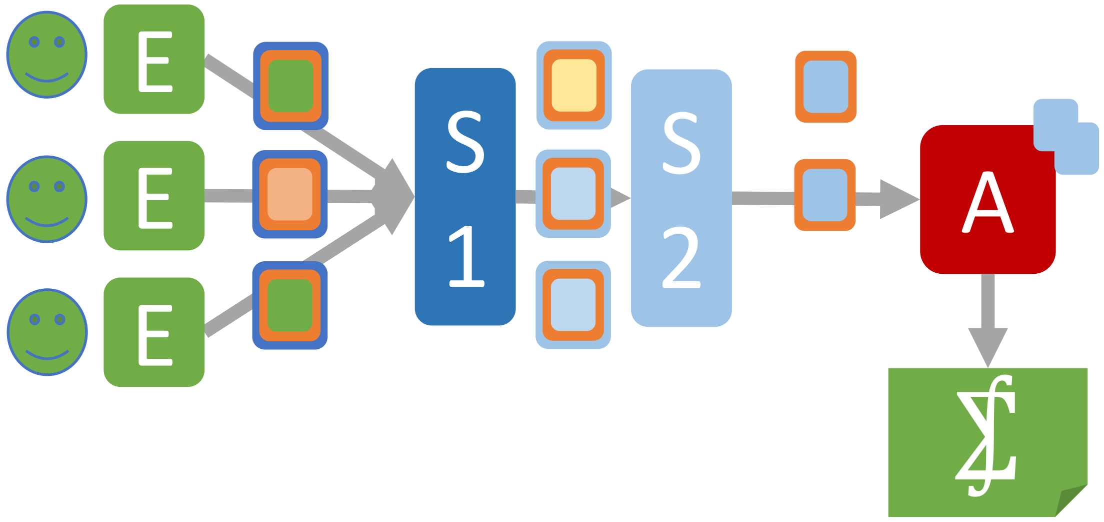


Randomized Thresholds, Blinding, and Crowd-based DP

Randomized thresholding gives another form of DP



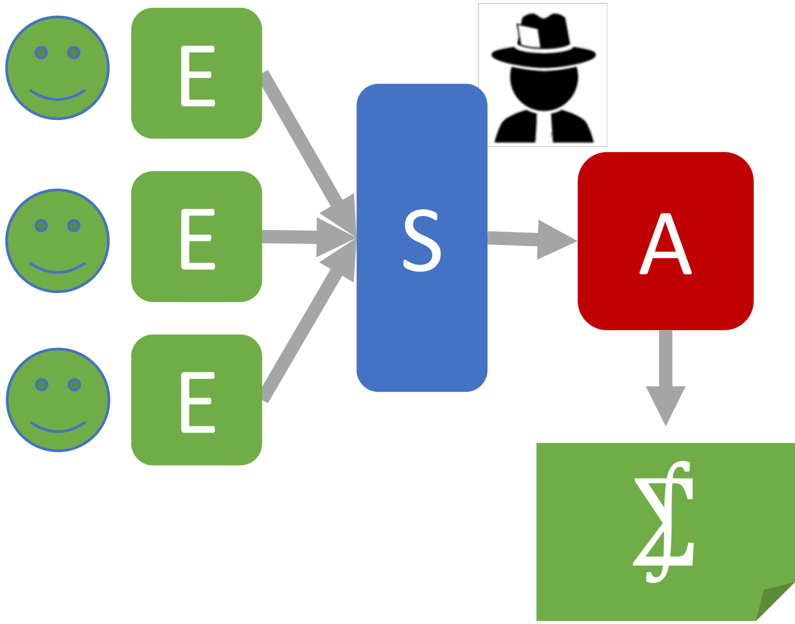
Blinding & Crowd Thresholding



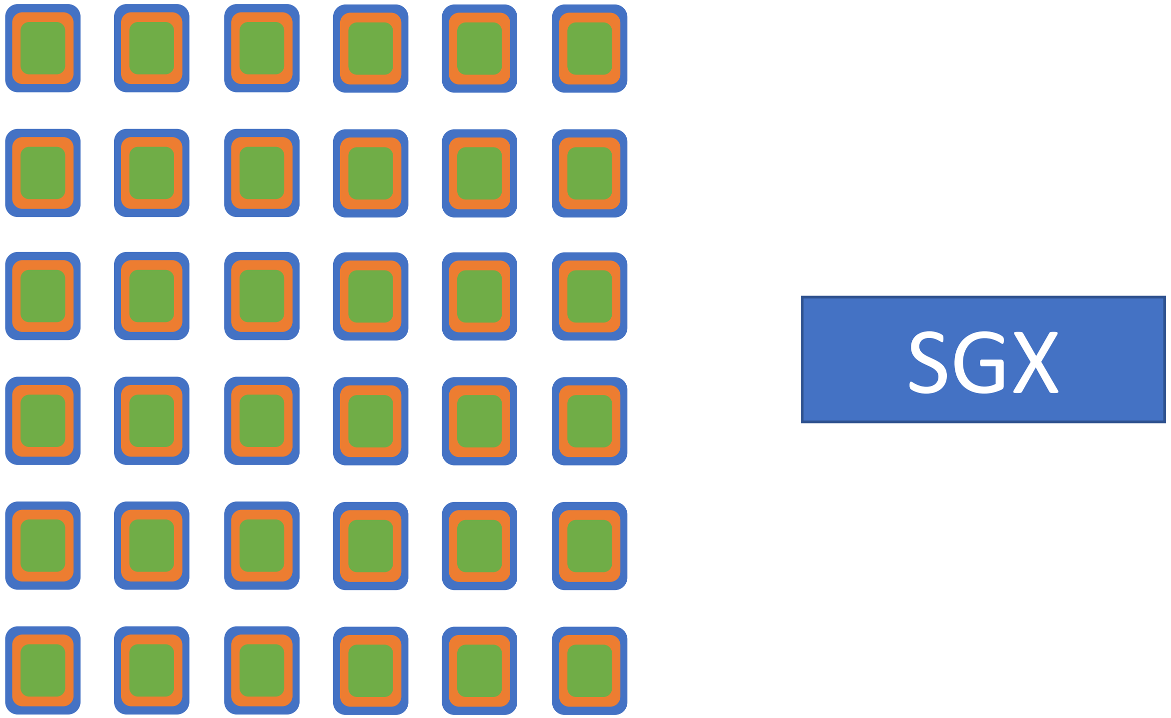
+ Cryptographic blinding of crowds

Risks in the ESA Shuffler

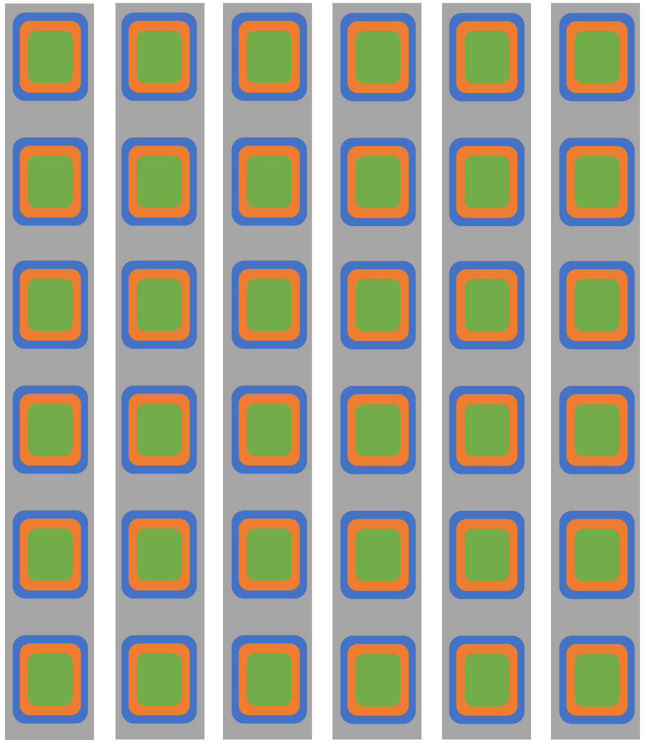
- Shuffling must be protected, isolated & opaque
- Insider risk, accidental server logs, etc.
- Malicious traffic analysis
- Prochlo
  - Hardened implementation of ESA shuffler
  - SGX + oblivious shuffling



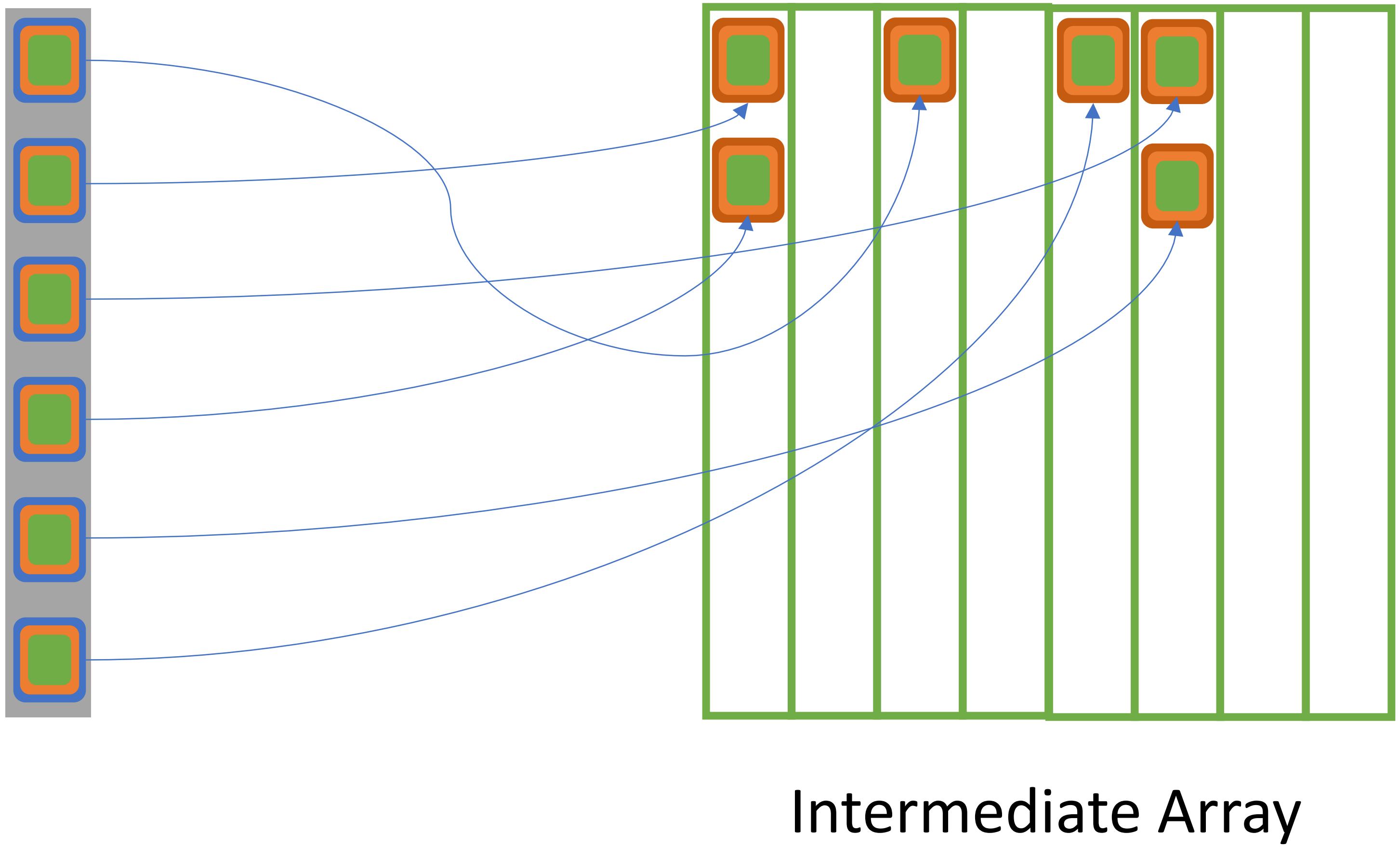
Prochlo StashShuffle



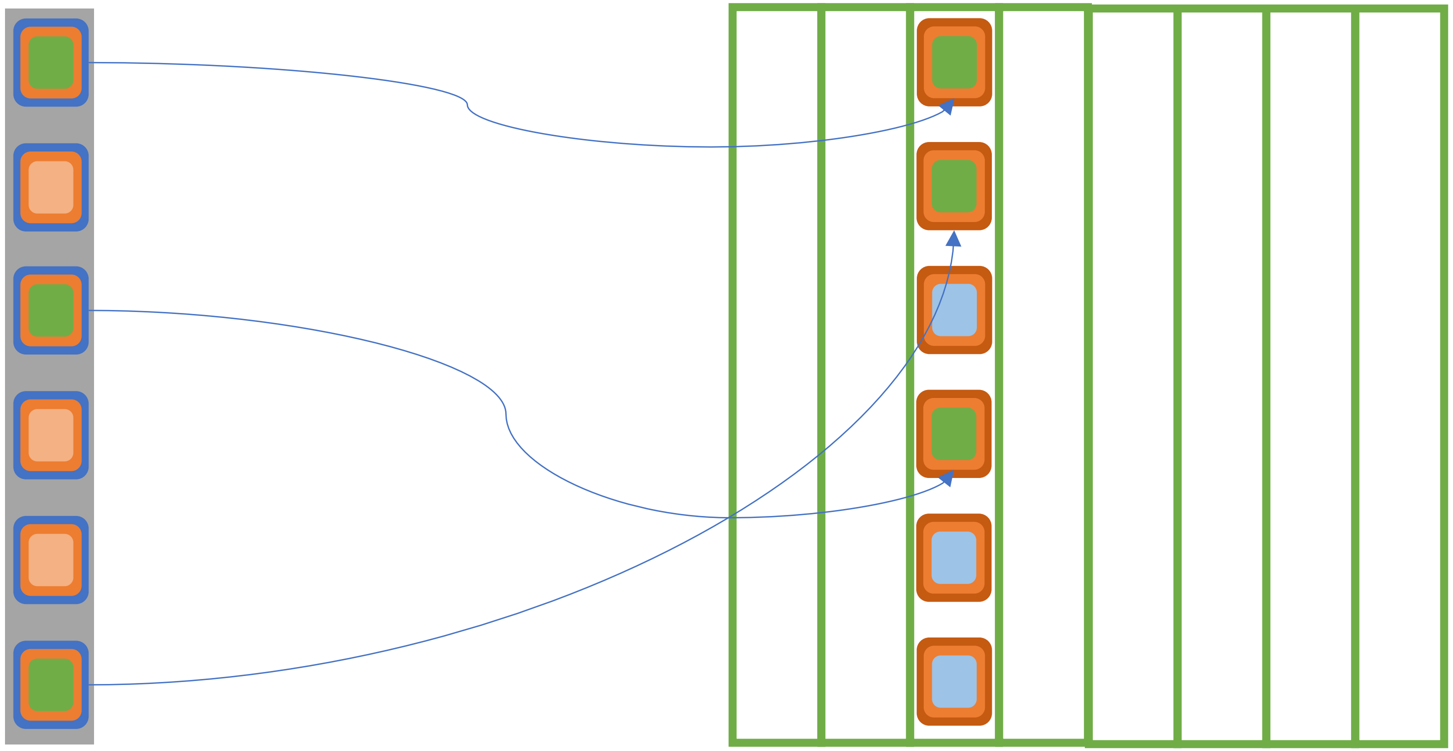
StashShuffle Buckets



StashShuffle Distribution

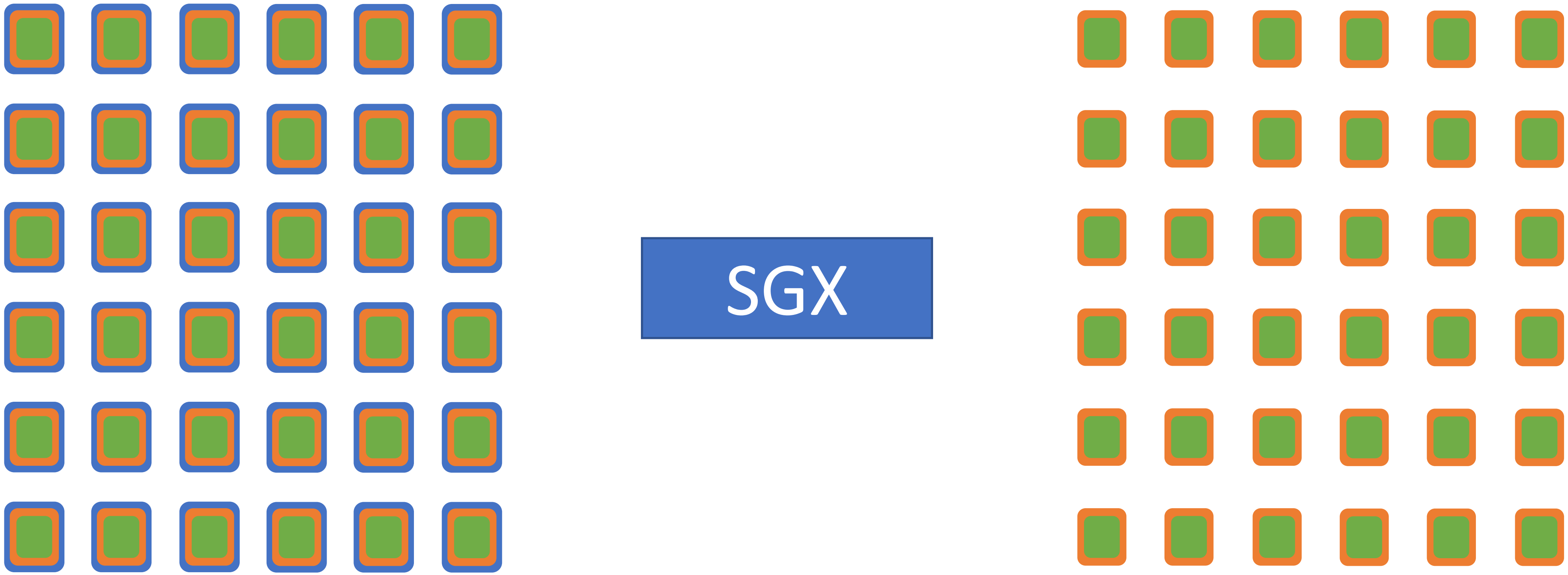


StashShuffle Compression



Output bucket

Prochlo StashShuffle

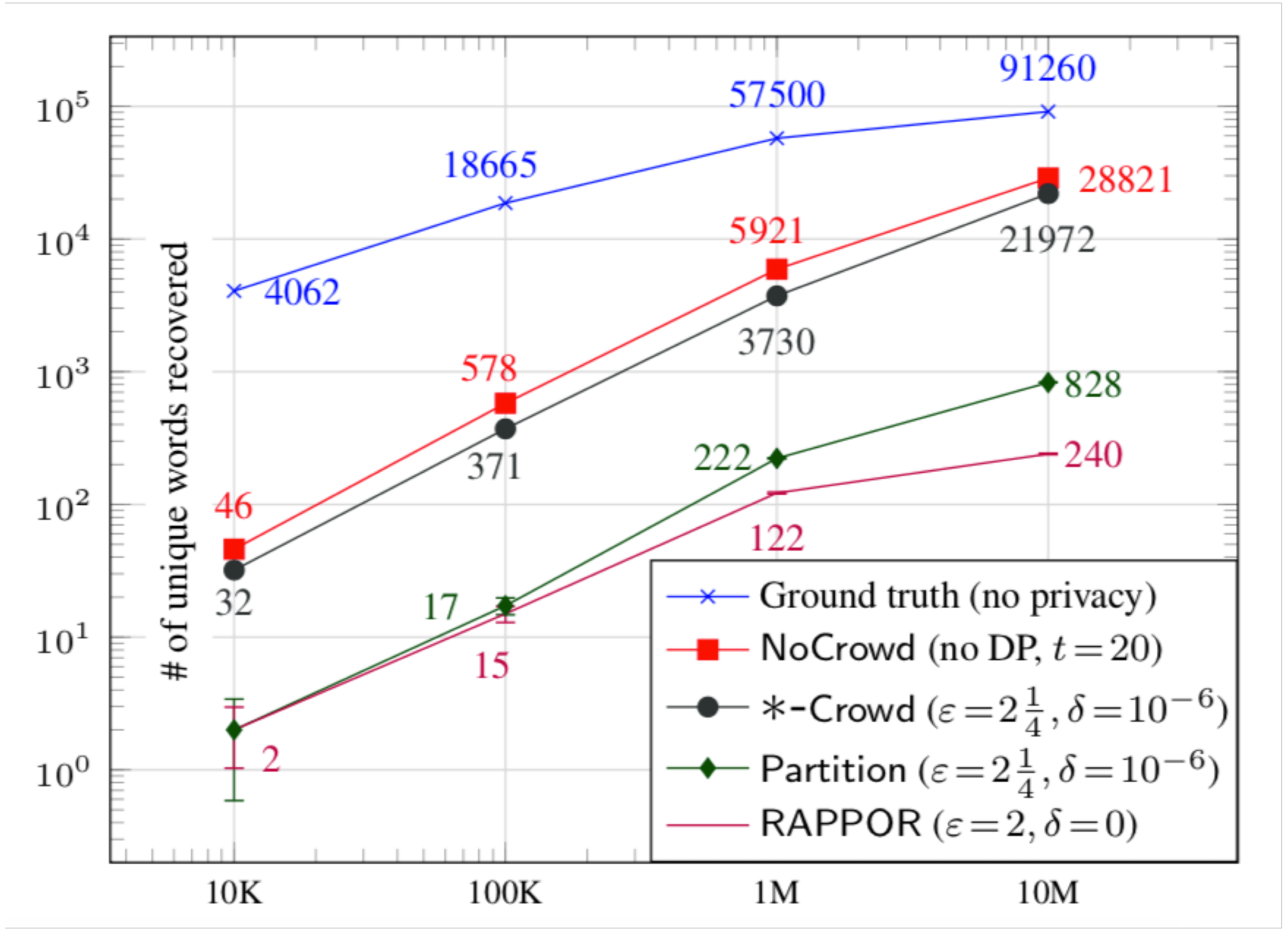


Shuffler Performance

N	Permutation strength	Time to shuffle	SGX mem used	Overhead of passes
10M	2^{-80.1}	738 s	22 MB	3.5x
50M	2^{-81.8}	1 h	52 MB	3.4x
100M	2^{-81.9}	2.1 h	78 MB	3.7x
200M	2^{-64.5}	4.1 h	69 MB	3.3x

Utility Performance

# of unique words recovered



# of vocab words

More experiments

- Perms: User Action Regarding Permissions
  - Multidimensional like API example
  - High utility with strong privacy $\varepsilon = 1.2$, $\delta = 10^{-7}$
- Suggest: Predicting the Next Content Viewed
  - High utility with intuitive privacy guarantee due to fragments
- Flix: Collaborative filtering
  - Utility equals state-of-the-art joint-distribution model
  - Strong privacy ($\varepsilon = 2.2$) + anonymity = no chance of re-identification

Conclusion

- Making strong privacy suitable for use in standard software engineering
- Open source:
  - https://github.com/google/rappor
  - https://github.com/google/prochlo
  - https://fuchsia.googlesource.com/cobalt/

Discussion

- ”Just trust Intel” vs. “Just trust Google”
- Attack model: “Shuffler is honest-but-curious”
- Large latency