Verifiable Distributed Aggregation Functions

draft-patton-cfrg-vdaf-01

Presented at IETF 113 (CFRG)

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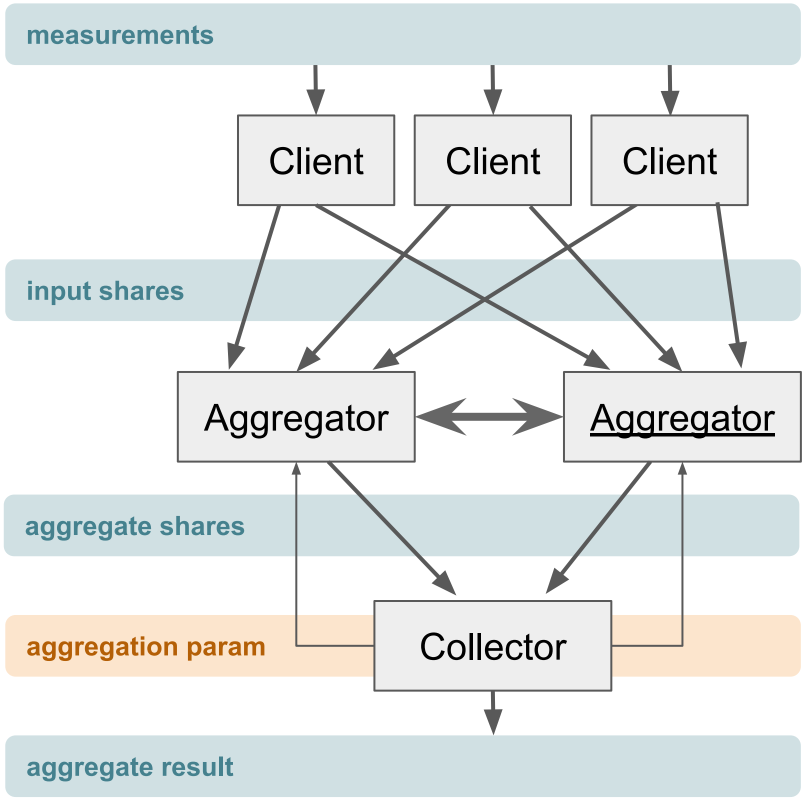
Context

- PPM working group's objective is to standardize multi-party computation for privacy preserving measurement
  - draft-gpew-priv-ppm-01 – the "PPM protocol", candidate for PPM working group adoption
    - Specifies end-to-end verification and aggregation of measurements over HTTPS
  - *This document* (draft-patton-cfrg-vdaf-01) – The core cryptographic component of the PPM protocol
- Ask for the CFRG: **Is draft-patton-cfrg-vdaf-01 ready for adoption by the working group?**

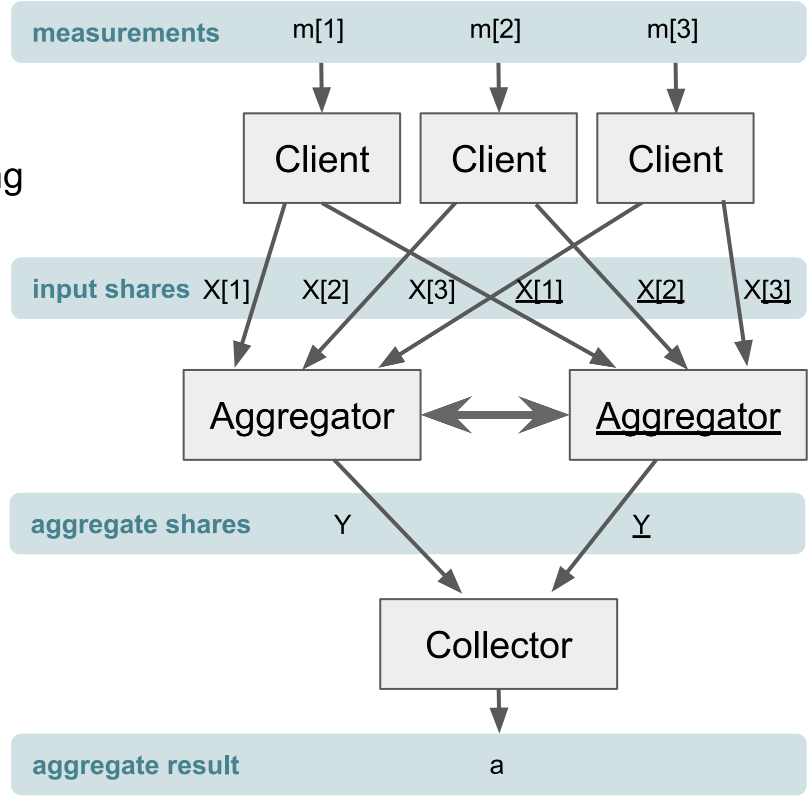
Overview of VDAFs

1. **Shard** – Each Client splits its *measurement* into *input shares* and sends one share to each Aggregator.
2. **Prepare** – Aggregators prepare each set of input shares for aggregation. Input shares are mapped to *output shares* using an optional *aggregation parameter.*
3. **Aggregate** – Each Aggregator combines its output shares into an *aggregate share* and sends it to the Collector.
4. **Unshard** – Collector combines aggregate shares into the aggregate result.



Candidate Constructions – Prio [CGB17, BBCG+19]

1. **Shard** – Client i splits m[i] into secret shared vectors X[i] and $\underline{X[i]}$ over some finite field.
2. **Prepare** – For each i, Aggregators interact among themselves in order to verify that X[i] + $\underline{X[i]}$ is a *valid* input.
3. **Aggregate** –
   - First aggregator: Y = X[1] + X[2] + X[3]
   - Second aggregator: $\underline{Y} = \underline{X[1]} + \underline{X[2]} + \underline{X[3]}$
4. **Unshard –** Collector computes a = Y + $\underline{Y}$.



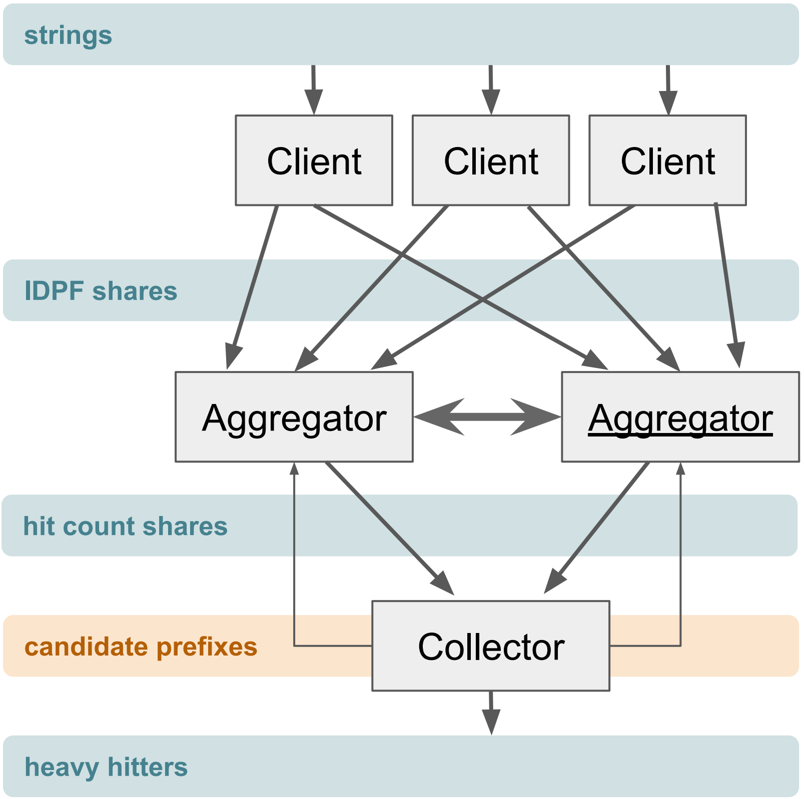
Candidate Constructions – Poplar [BBCG+21]

- Problem: securely compute the *heavy hitters*
  - Measurements: N-bit strings
    - (N=3) 000, 111, 010, 011, 100, 110, 100, 010, 010, 101, 001
  - Aggregate result: Strings with at least T *hits*
    - (T=2) 010, 100

- Solution: *Incremental Distributed Point Functions (IDFPs)*
  - Clients split their measurement into *IDPF shares*
  - Aggregators *query* IDPF shares on *candidate prefixes*
    - Input = 011: Is 0 a prefix? *Yes*; Is 1 a prefix? *No*; Is 01 a prefix? *Yes*; …
  - Each aggregator holds a share of each query output.
    - Output shares are aggregatable into *hit counts*, i.e., the frequency of each candidate prefix.

Candidate Constructions – Poplar [BBCG+21]

1. **Shard** – Client generates IDPF shares from its input string.
2. **Prepare** – Each Aggregator queries its IDPF share at each candidate prefix. Aggregators interact in order verify the output shares are well-formed (without revealing the output).
3. **Aggregate** – Each Aggregator combines its output shares into a share of the hit count for each candidate prefix.
4. **Unshard** – Collector combines hit count shares to get hit counts of each candidate prefix. *(Hit counts used to compute the next set of candidate prefixes.)*



Progress since IETF 112

- Minor syntax improvements
- Complete spec of **Prio**, including a reference implementation for generating test vectors
  - Reference implementation (Sage): https://github.com/cjpatton/vdaf/tree/main/poc
  - Rust implementation: https://docs.rs/prio/0.7.0/prio/vdaf/prio3
    - Lots of room for optimization, but fast enough for now

VDAF	Client runtime	Client communication
Prio3Aes128Count	11.3 us	80 bytes
Prio3Aes128Histogram (10 buckets)	22.6 us	768 bytes
Prio3Aes128Sum (32 bits)	47.2 us	2,656 bytes

Next Steps

- Complete spec of **Poplar**
  - Incomplete implementations exist, none are interoperable.
    - C++: https://github.com/google/distributed_point_functions
    - Rust: https://docs.rs/prio/0.7.0/prio/vdaf/poplar1
- Security analysis and fleshed out security considerations
- More VDAFs! Either in this document or elsewhere
- Enumeration of open issues: https://github.com/cjpatton/vdaf/issues

References

- [CGB17] Corrigan-Gibbs-Boneh. "Prio: Private, Robust, and Scalable Computation of Aggregate Statistics". NSDI 2017.
- [BBCG+19] Boneh et al. "Zero-Knowledge Proofs on Secret-Shared Data via Fully Linear PCPs". CRYPTO 2019.
- [BBCG+21] Boneh et al. "Lightweight Techniques for Private Heavy Hitters". IEEE S&P 2021.