Rabbit-Mix

Robust Algebraic Anonymous Broadcast from Additive Bases

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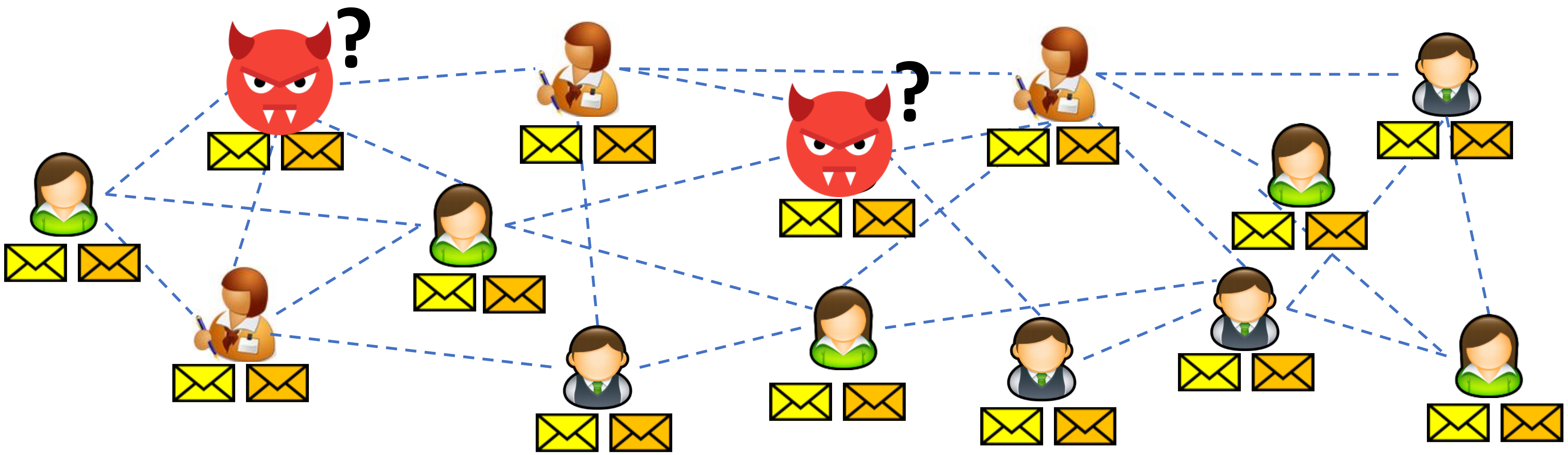
Anonymous Broadcast

- Senders
  - Senders have messages
- Receivers
- **Goal**: All honest receivers receive all m's from all honest senders (i.e., broadcast)
  - Adversary cannot interrupt honest participants
  - Adversary cannot link messages with messages (sender-anonymity)



Main Approaches

- Onion routing
  - [Tor, Dandelion, …]
- Mixing network
  - [Loopix, Miranda, …]

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- Practical scalability and latency
- Vulnerable to traffic analysis
  - Statistical analysis
  - AI/ML analysis
- Subtle privacy/security definitions

- MPC-based mixing network
  - Dining Cryptographer network
  - [Riposte, MCMix, AsynchroMix, PowerMix, Blinder, Express, Sabre, RPM]

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- Relatively less practical scalability and latency
- Cleaner privacy/security definitions
- Cryptographic security guarantees of non-linkage

Possible Applications

- Anonymous Anti-censorship Public Bulletin/Posting Systems
  - Human-rights violation reporting
  - Whistleblowing – Governmental/Organizational Corruption
  - Public journalism movement under Oppressive Regimes
  - .....

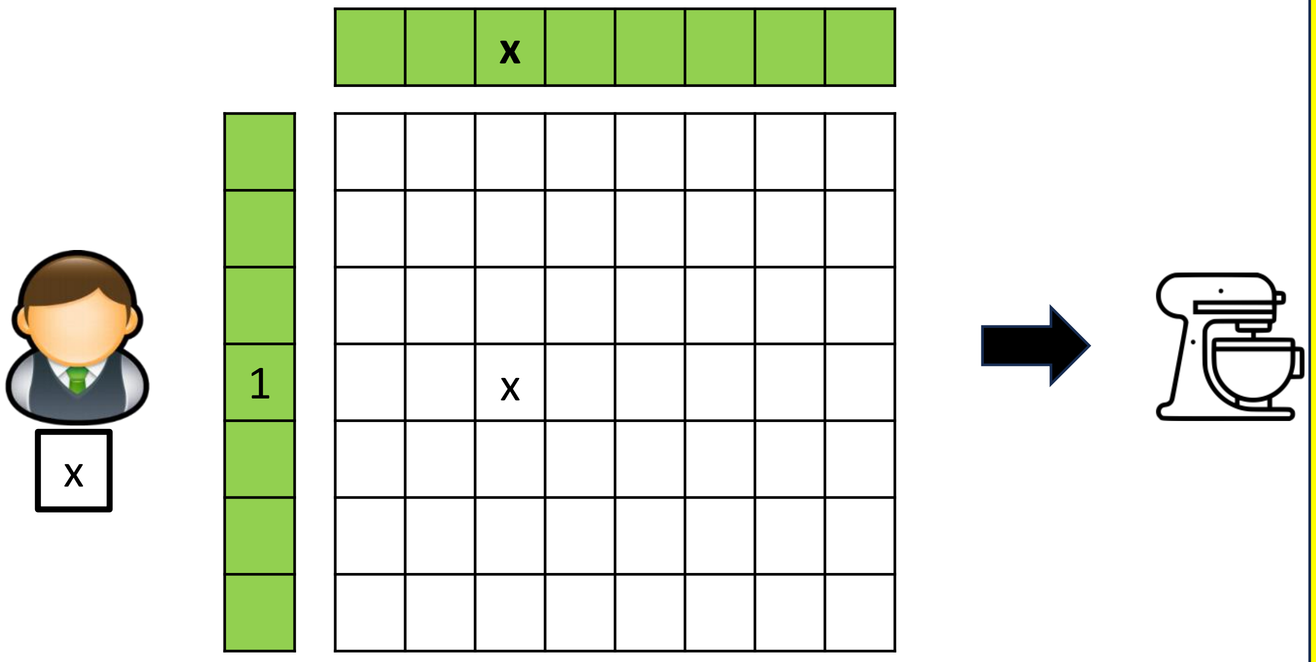
Robust Anonymous Broadcast

- Functionality in Client-Server Multiparty Computation (MPC) paradigm
- N clients
  - Each client has message m_i
- n servers - a mixing committee
- Clients submit m_i to the mixing committee (e.g., secret-shares m_i to servers)
- n servers executes a MPC protocol to mix (e.g., shuffle) and output messages to the clients
- **Goals:**
  - Small constant round complexity
  - Sublinear communication from clients to servers
  - Negligible message delivery failure
  - Efficient offline computation
    - e.g., the MPC prep for the main MPC is as efficient as the main MPC

MPC Approaches and Previous Works

- Private Writing [Riposte, Blinder, ...]
  - A client sends ~ $5\sqrt{N}$
  - Server computation O(N^2)
  - 95% of messages expected to be output (5% needs to be resent)

- **Decompression**: Tensor of two vectors - O(N^2)
- Collisions between messages will destroy messages
- Use two tables each bigger by factor of 2.7

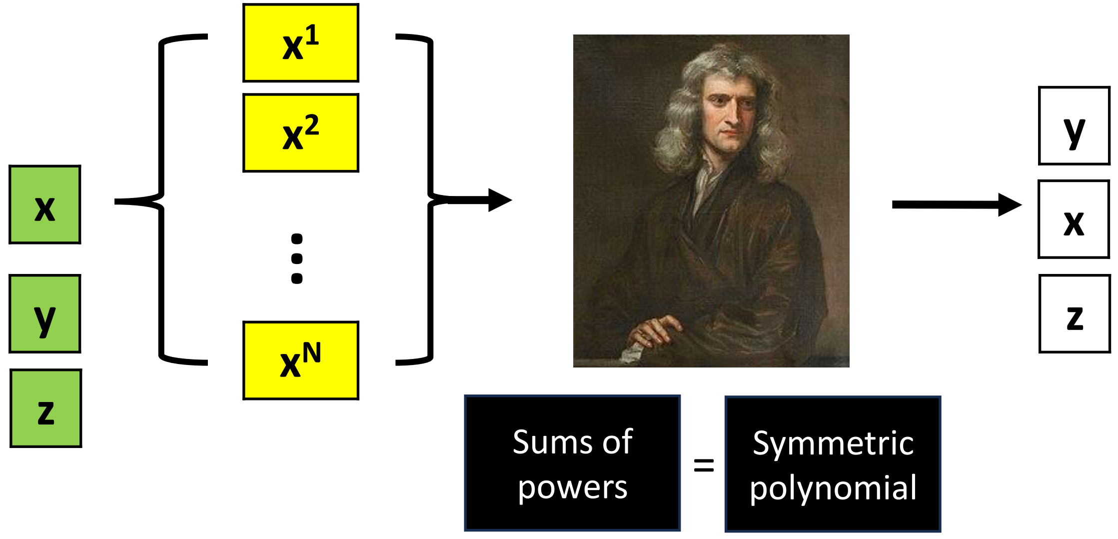


Bigger by factor of 22 for 99.9%

MPC Approaches and Previous Works

- Private Writing [Riposte, Blinder, ...]
  - A client sends ~ $5\sqrt{N}$ (redundancy)
  - Server computation $O(N^2)$
  - 95% of messages expected to be correct (5% needs to be resent)
- Newton's Identity [PowerMix]
  - A client sends 1
  - Server computation $O(N^3)$
  - 100% of messages expected to be correct

Decompression takes $O(N^3)$



Rabbit-Mix

- Goal 1: 100% message delivery rate
  - Newton's Identity

- Goal 2 & 3: Sublinear communication from Clients & $O(N^2)$ total server computation
  - Additive 2-basis

For simple additive 2-basis example, suppose N = 100

x

$O(N^3)$ computation
[Previous]

x^1
x^2
⋮
x^{100}

x

Optimized Additive 2-basis
[Mrose79]
- 7% reduction in size
- $2\sqrt{N}-1 \rightarrow$ **$1.87\sqrt{N}$**
(3X Better than Blinder)

$O(N^2)$ computation
→ Depth-1 local multiplications of two elements
[Our approach]

Rabbit-Mix

- Goal 1: 100% message delivery rate
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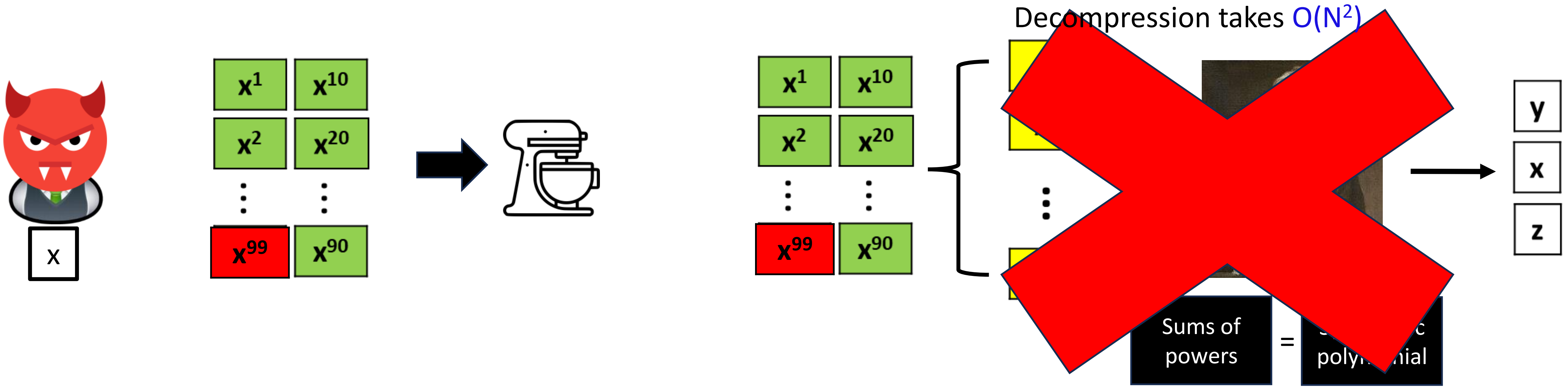
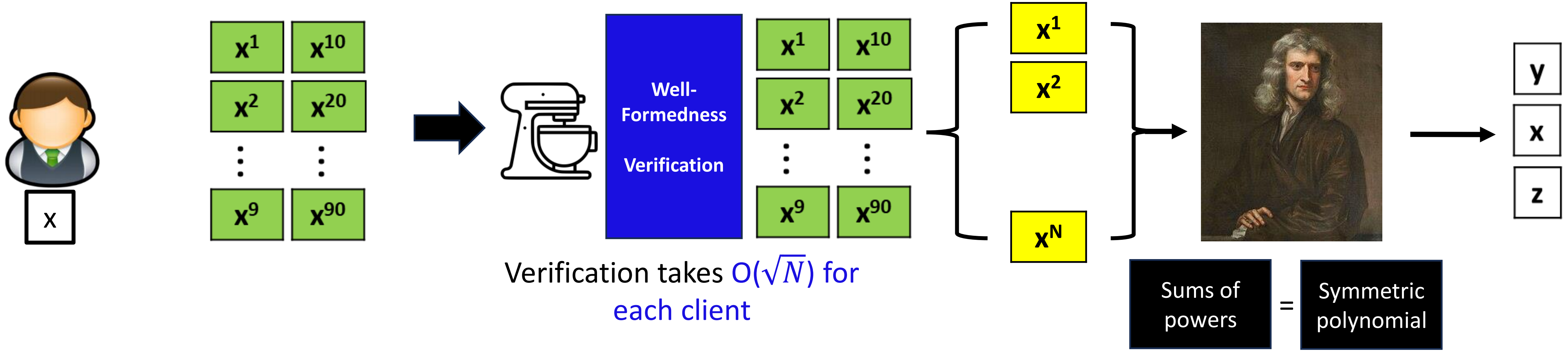
  - Additive 2-basis

Not Done Yet!!



Rabbit-Mix

- Goal 1: 100% message delivery rate
  - Newton's Identity
- Goal 2 & 3: Sublinear communication from Clients & $O(N^2)$ total server computation
  - Additive 2-basis
- Goal 4: Sieving malicious clients
  - Linear sketch for Additive 2-basis [BBCGI19, Blinder, ...]

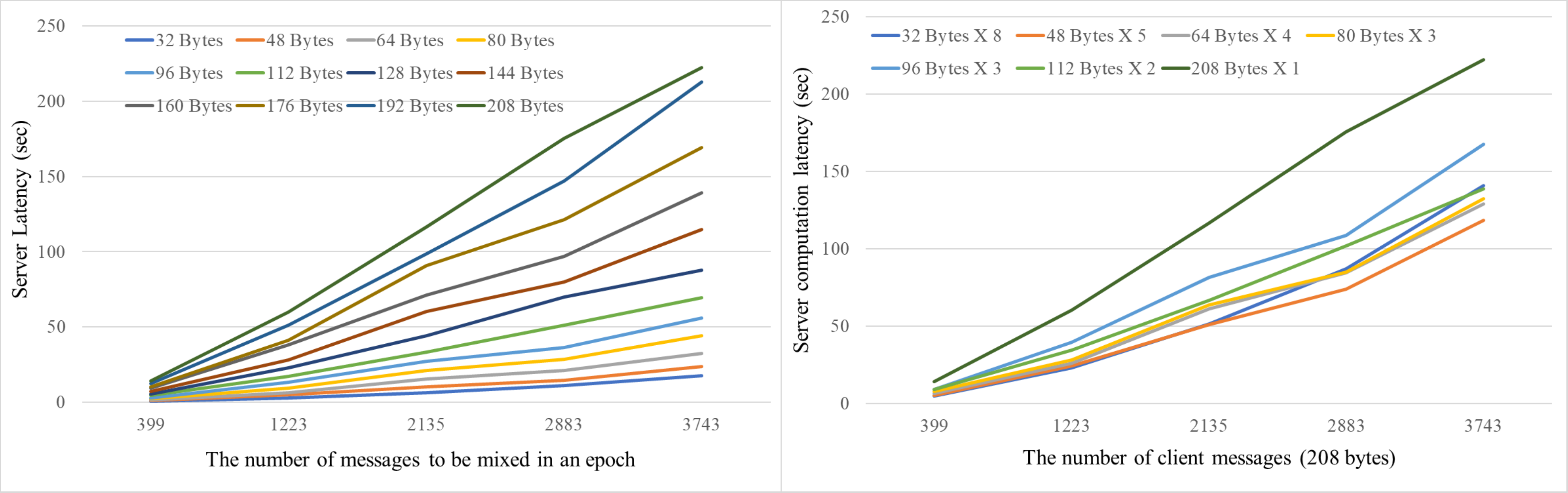


Implementation & Benchmarks

- Proof-of-concept
- C++ with NTL library
- Boost Asio for networking
- No parallelization used

- 6 AWS EC2 instances – c5d.9xlarge
  - 5 servers
  - 1 client – submit all messages

End-to-end latency with various primes and # of messages



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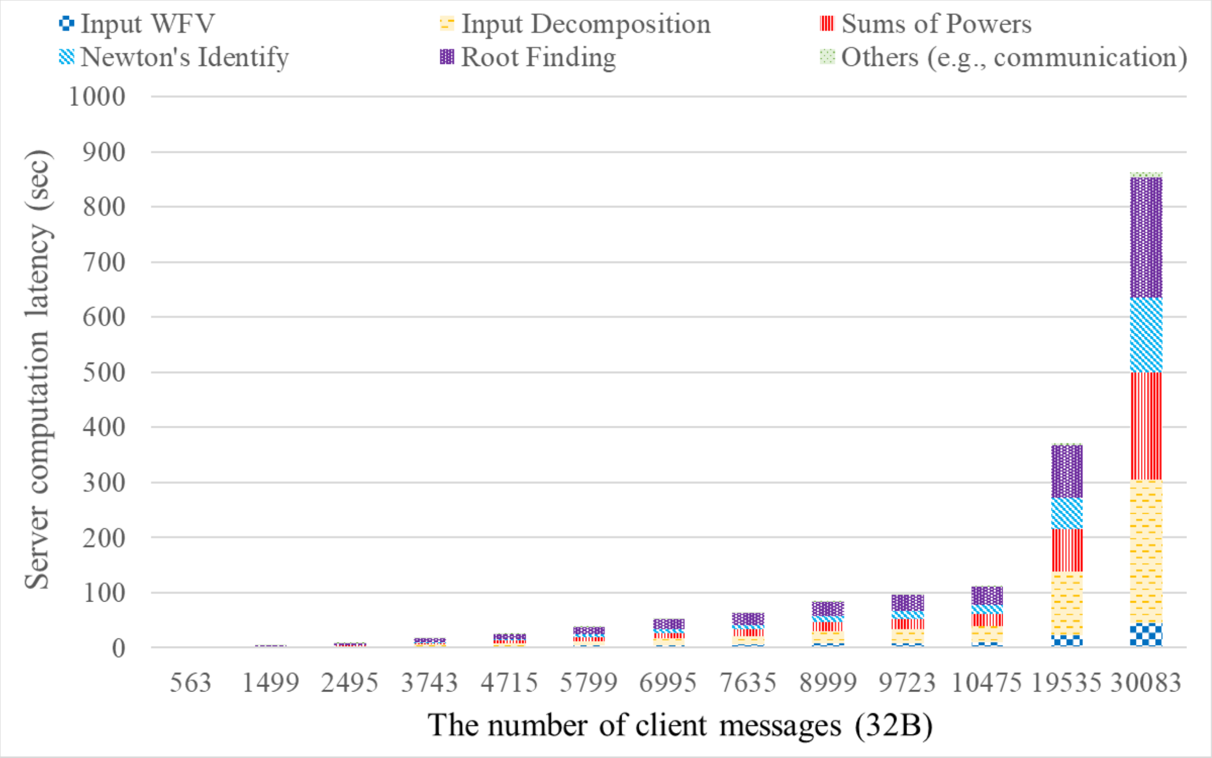
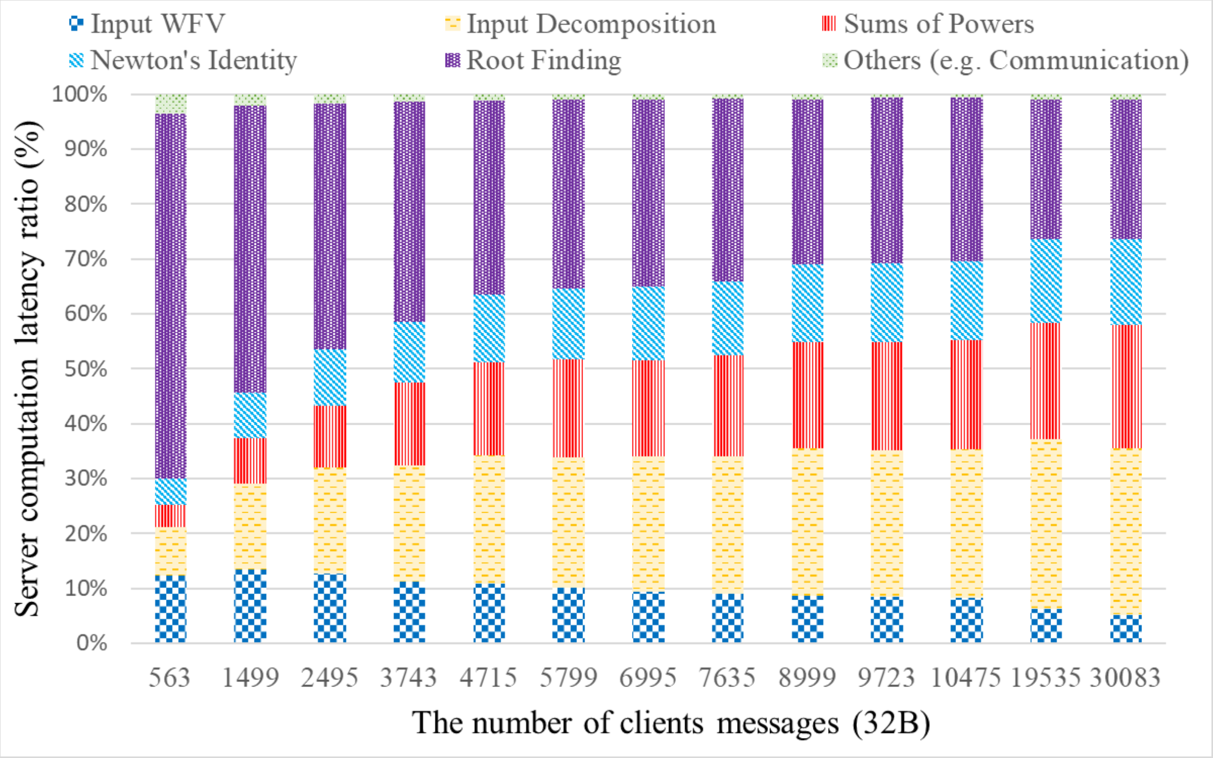
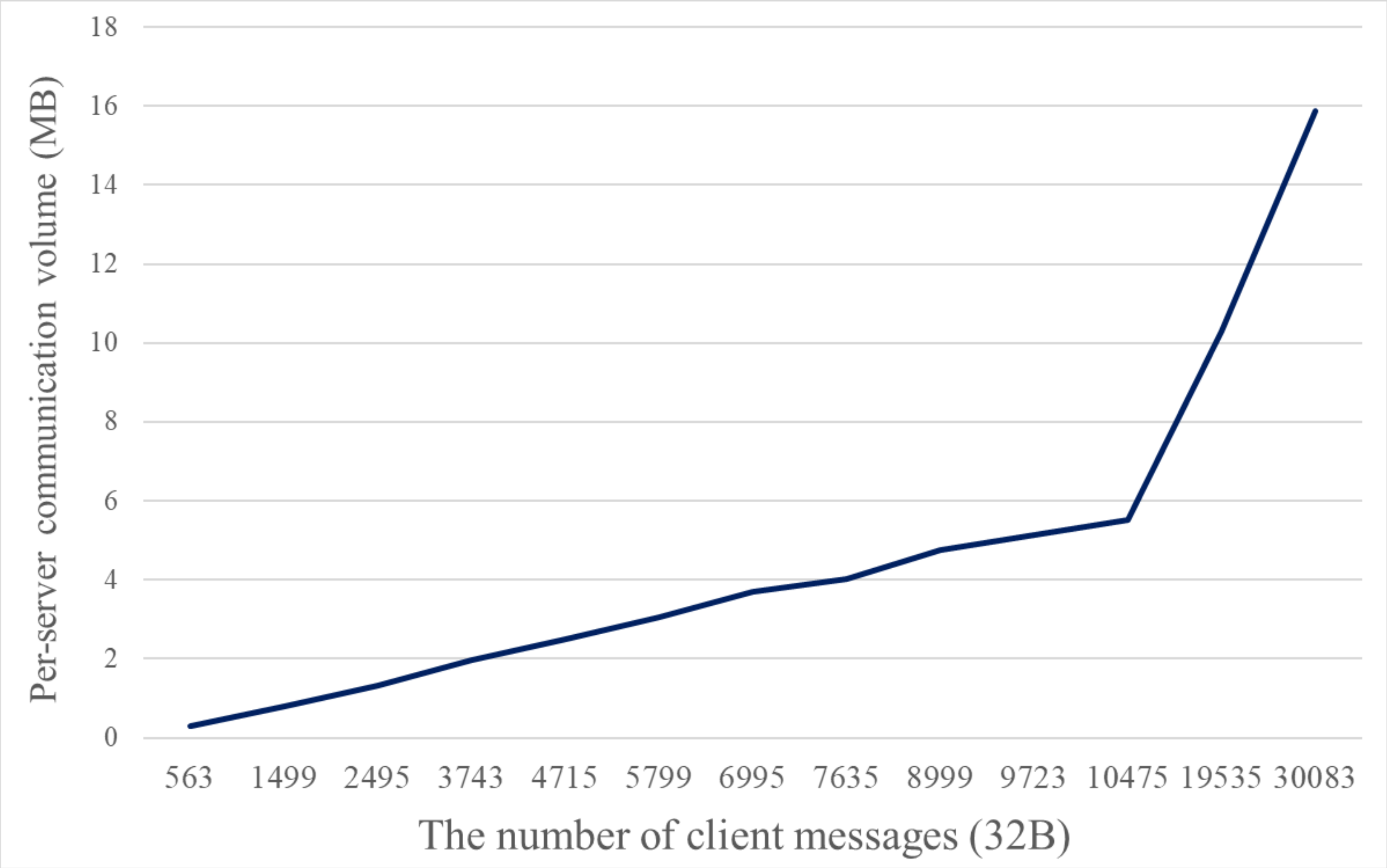
Extensive Latency and Subprotocols (32 byte messages)

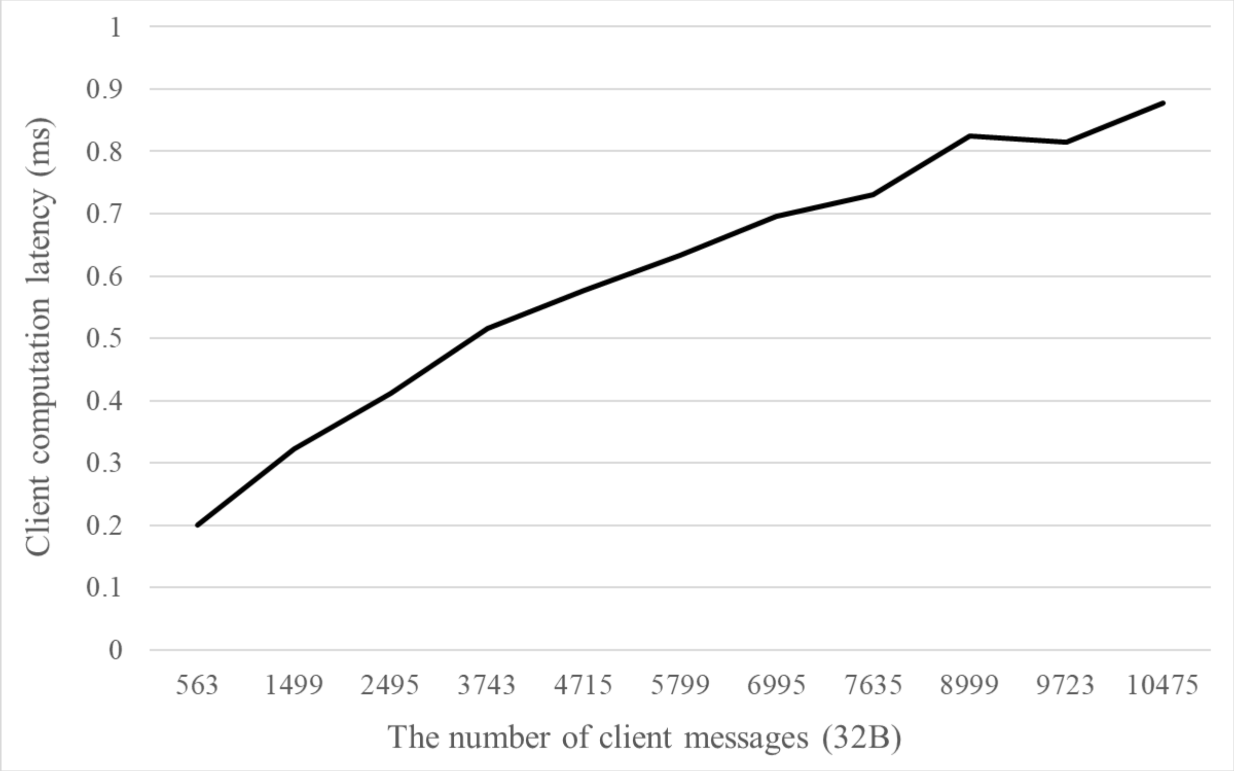


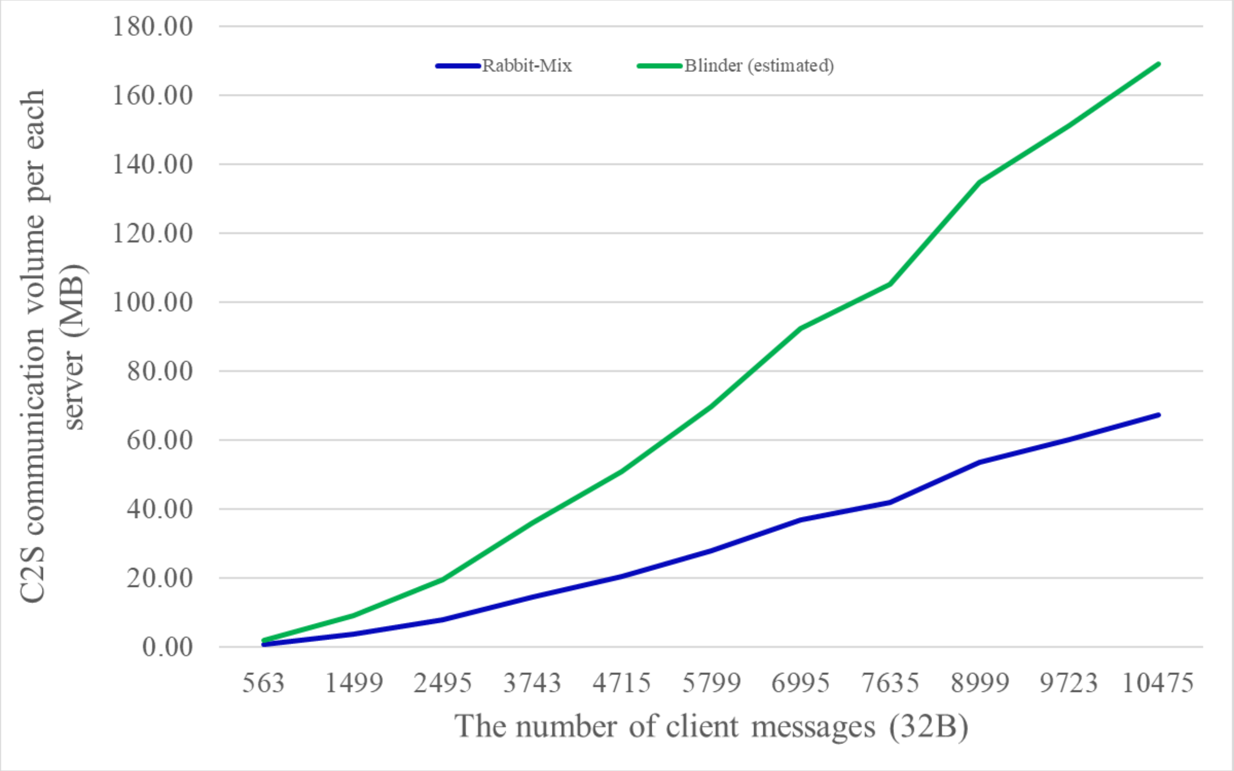


Server communication (32 byte messages)



Client computation and communication (32 byte messages)





Conclusion

- Improve client’s communication by 3X in comparison to Blinder (and other Private-Writing based protocols)
  - No need handle collisions
- Improved concrete server computation efficiency
  - 3X less operations in comparison to Blinder
- Efficient linear sketches for additive 2-basis
  - Verifying well-formedness over known arithmetic progressions
- Proof-of-concept implementation and benchmarks