OblivP2P: An Oblivious Peer-to-Peer Content Sharing System

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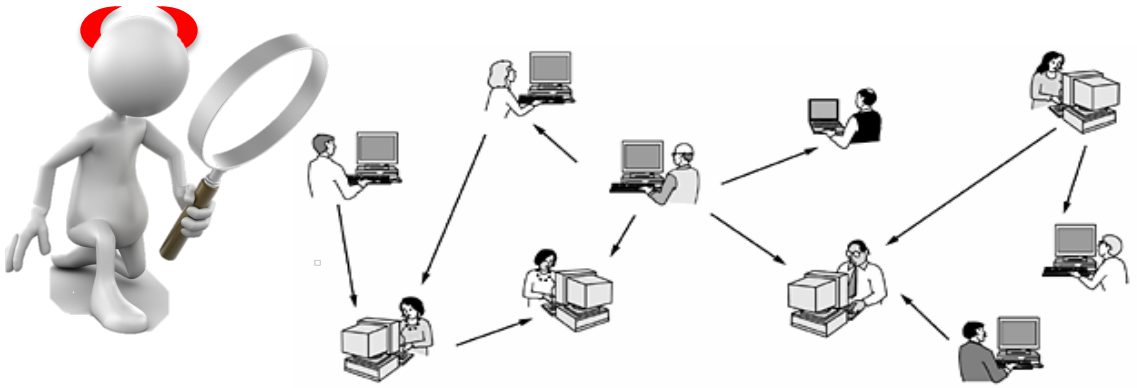
Traffic Analysis in P2P Systems

- P2P content sharing systems
  - 150 million users/month
  - **3.35%** of all world bandwidth

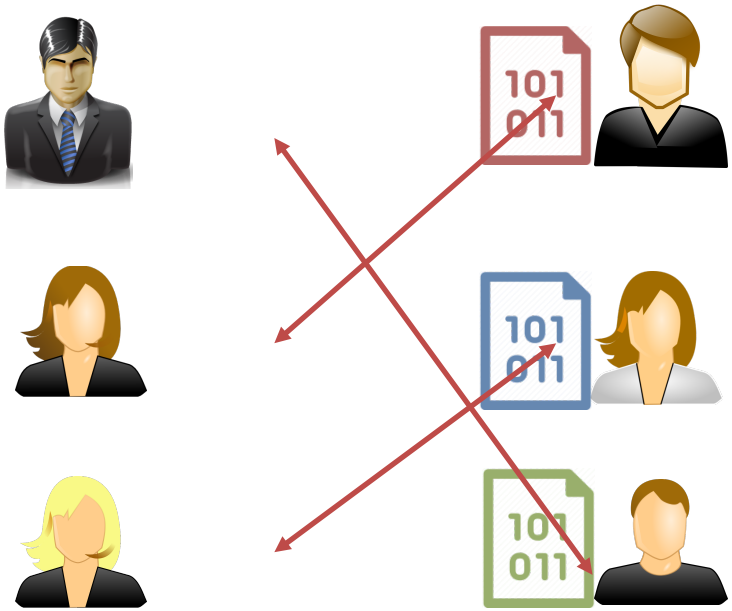


- Long term global traffic analysis
  - E.g., ISP's, Global BitTorrent Monitor, Bitstalker

What can an Adversary do?

- Leakage Channels
  - Plaintext data
    - Secure channel
  - Length
    - Padding
  - Time
    - Fixed Interval

Assume existing defenses



Linkability

- **Access Patterns**

Problem

Current Solutions

- Anonymous Systems e.g., Mix Networks, Tor

Hide Online Identity

Unlinkability

Adversary

✓Long term

✓Global

Is anonymizing enough?

Contributions

OblivP2P Protocol

- Guarantee unlinkability
- Obliviousness in P2P systems

Implementation

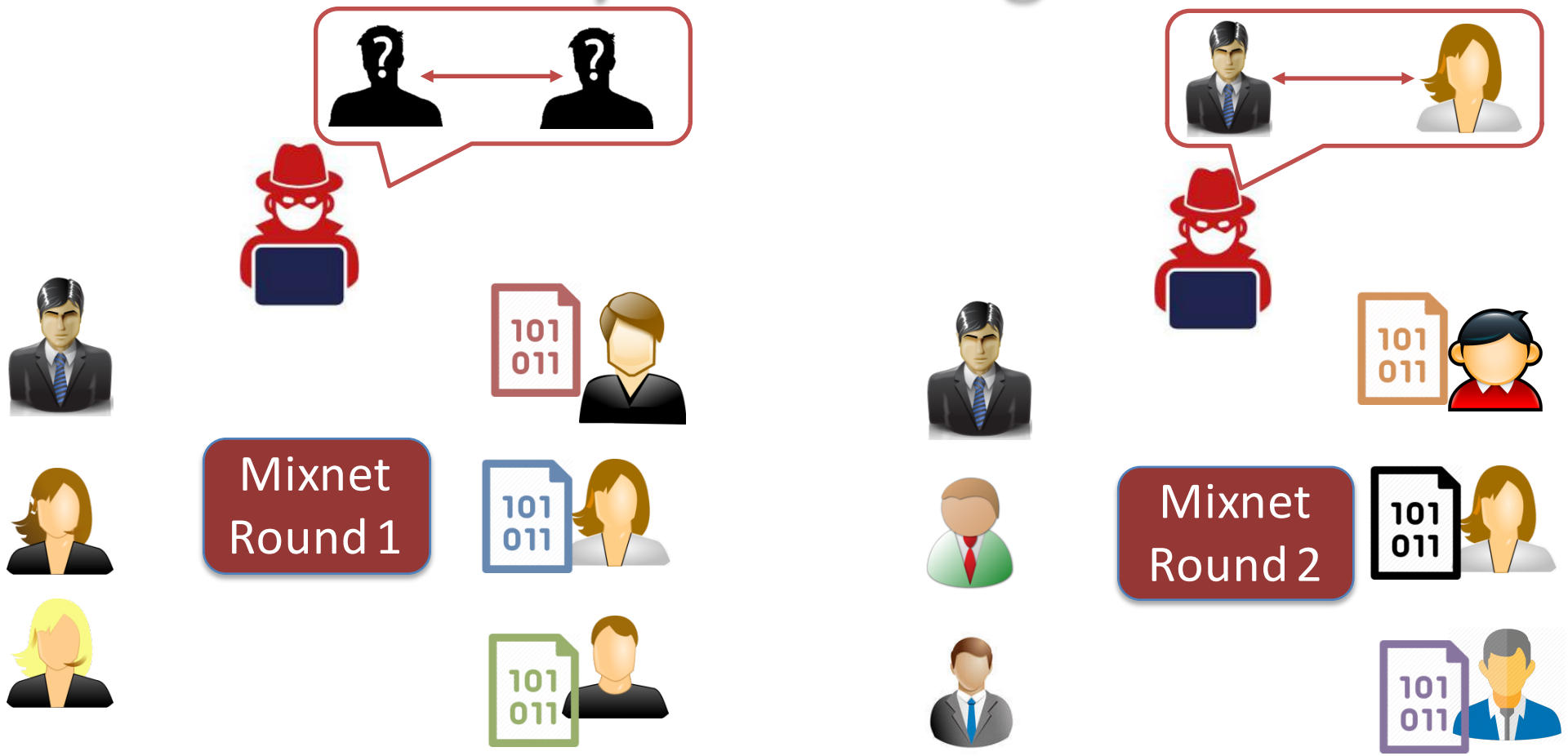
- Link: https://github.com/jiayaoqijia/OblivP2P-Code

Evaluation

- No Centralized Bottleneck
- Linear Scalability with peers

Problem

Insufficiency of Existing Solutions

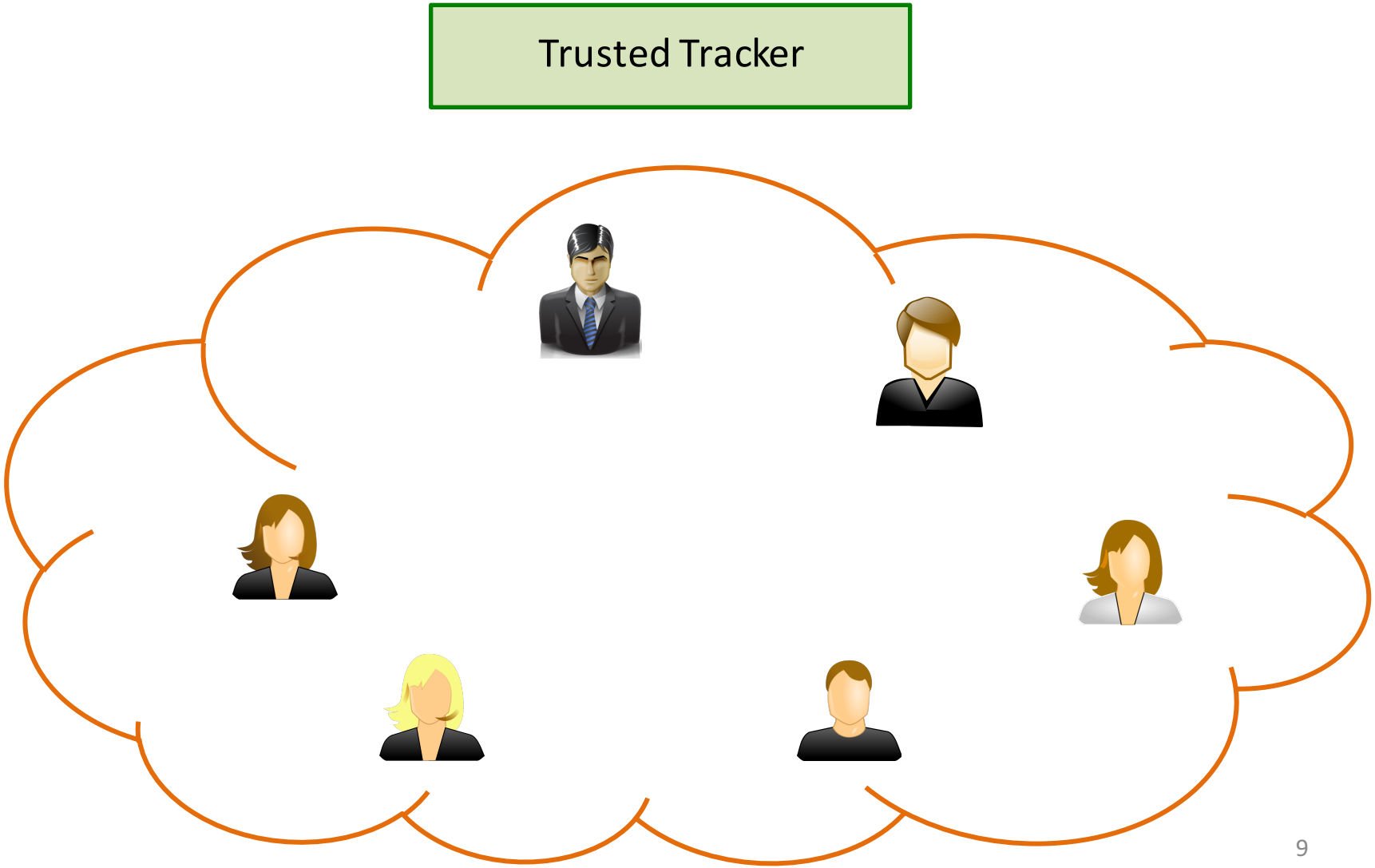


Intersection, Hitting Set [AK'03] or
Statistical Disclosure Attacks [KP'04]

Main Insight: Oblivious Access Pattern

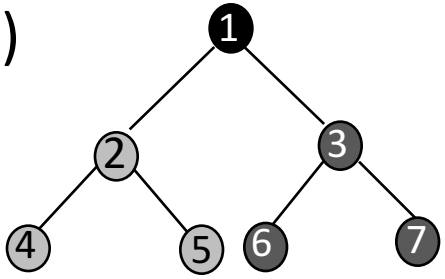
- Oblivious RAM
  - Hide access patterns between CPU and memory
  - Data is shuffled in the memory periodically
- Applied to:
  - Cloud Storage [SS'13A], [SS'13B],[LO'13]
  - Filesystem [WST'12]
- *Can we directly apply ORAM to P2P systems?*

Problem Definition

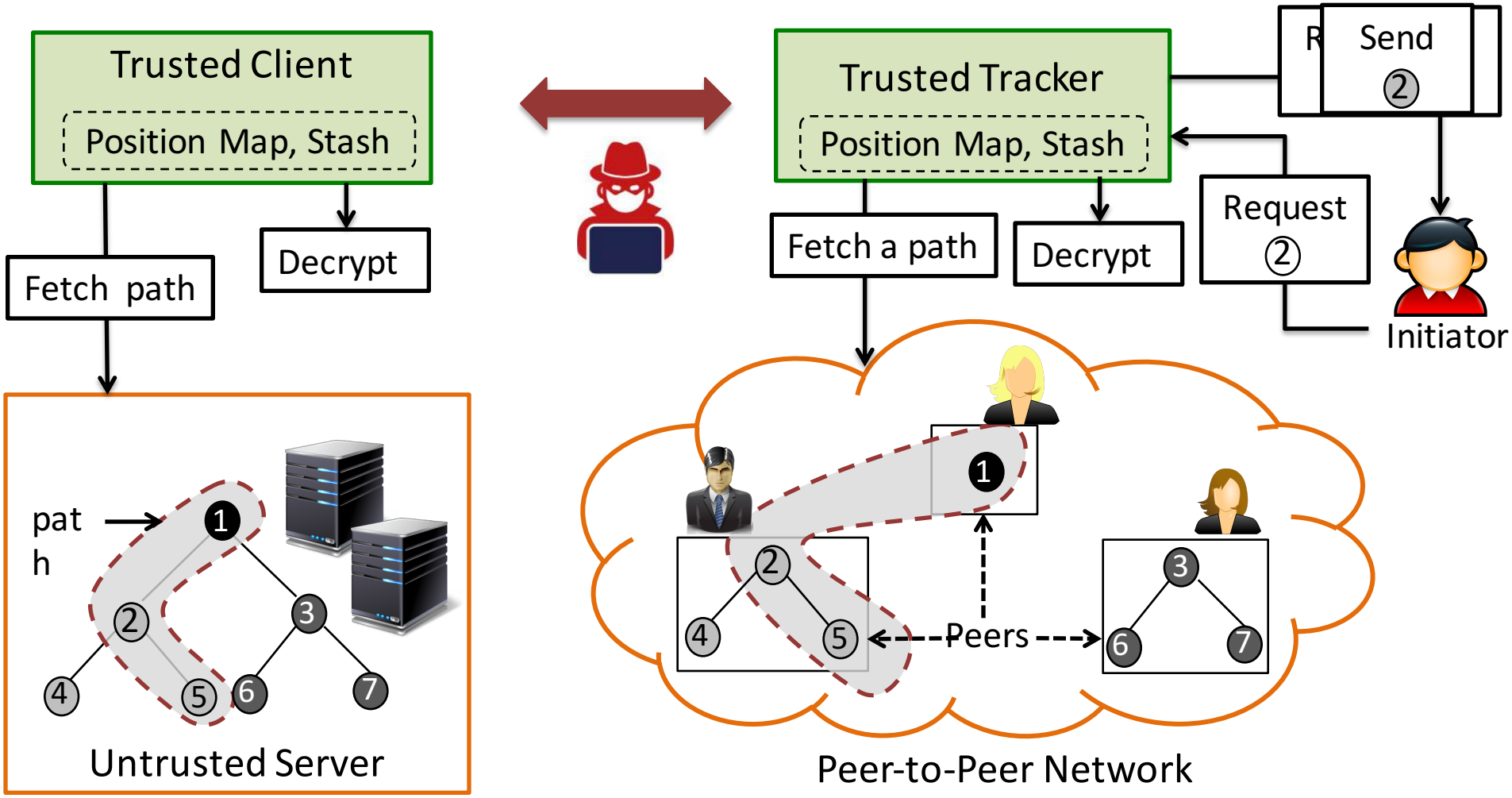


ORAM Background

- Tree-Based ORAM (Path ORAM)
  - *Read*
    - Fetches a path from the tree containing the block
    - Stores the path in the local storage (stash)
  - *Write*
    - Selects a random path in the tree
    - Shuffles the blocks in the stash and the path



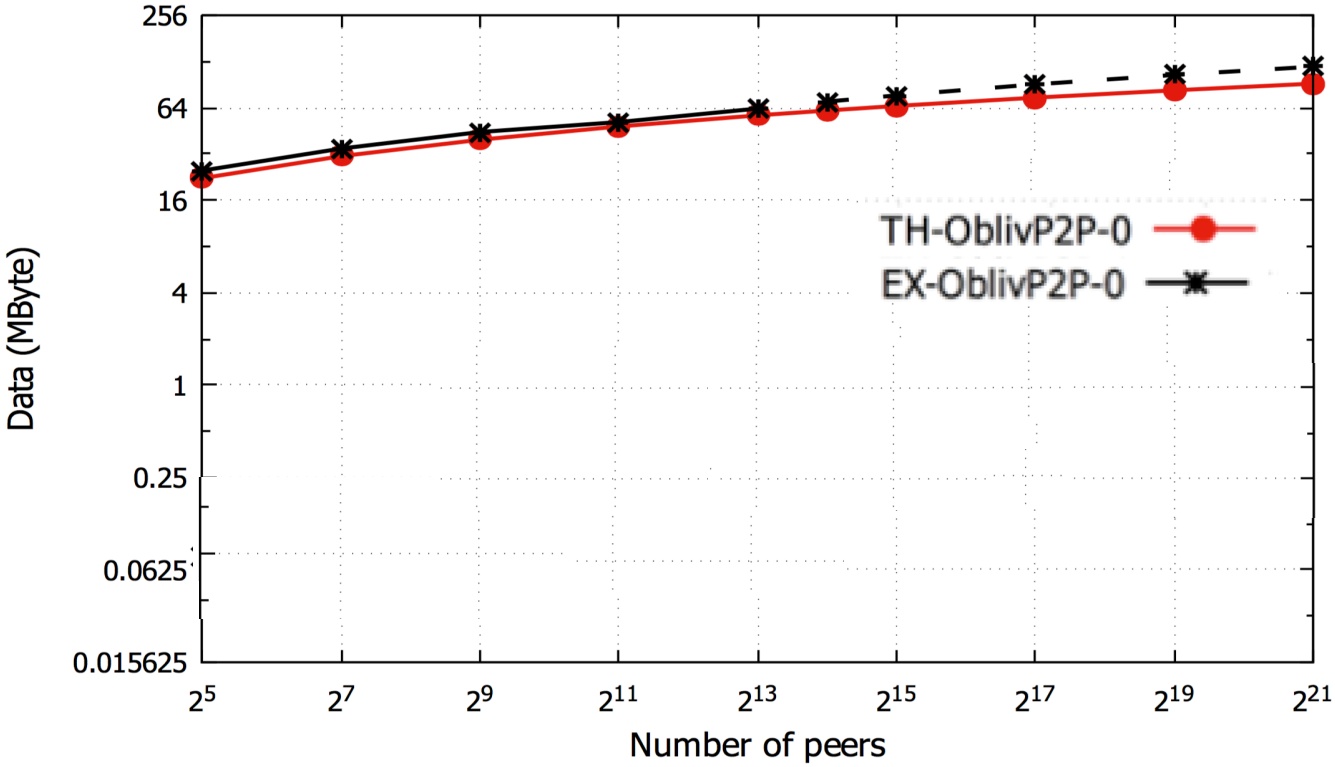
Mapping ORAM to P2P



OblivP2P-0 Protocol

OblivP2P-0: Tracker as bottleneck

- Tracker fetches O(log N) blocks per access



118 MB /req
for 2 million users
≈ Max Bandwidth

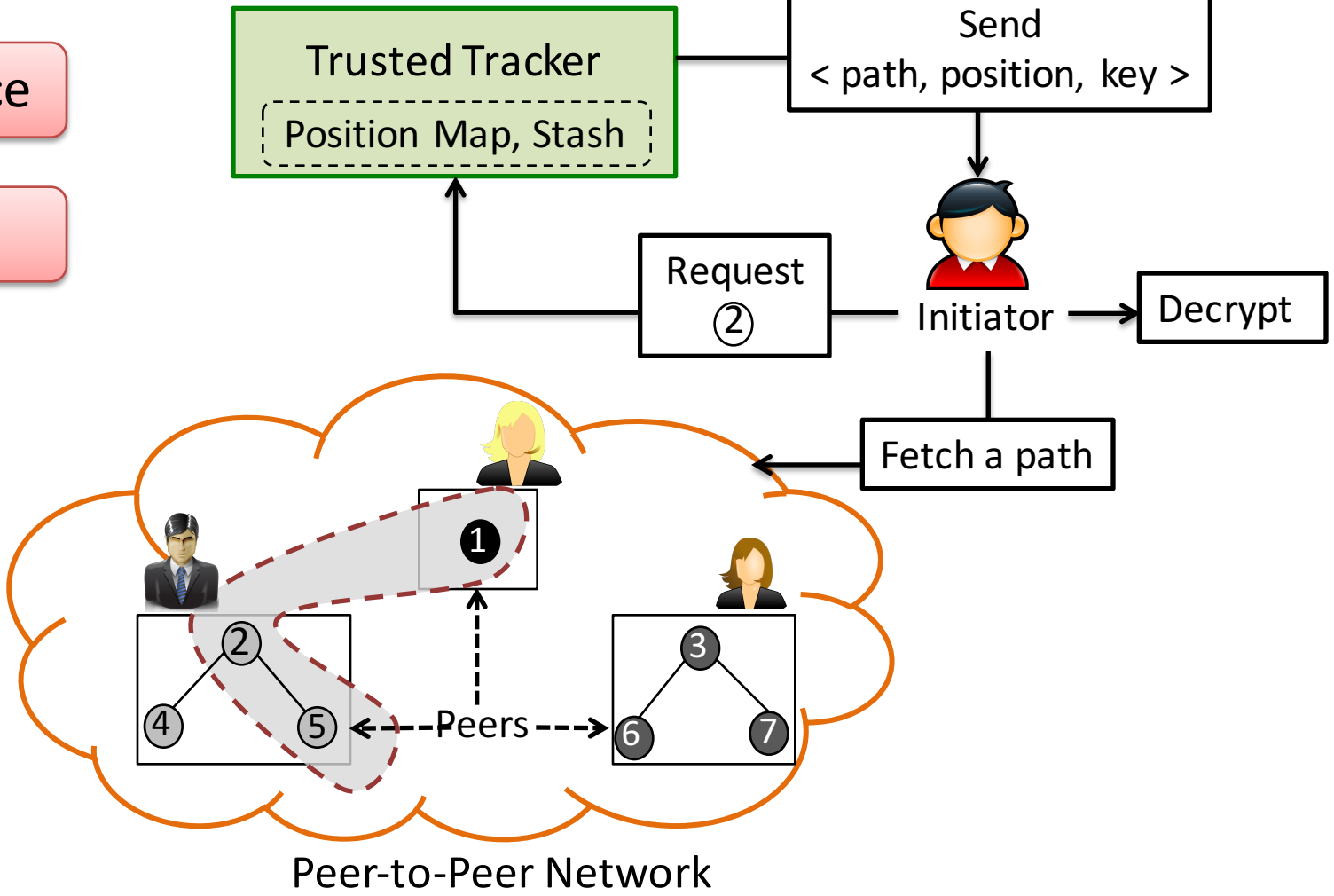
Need a Distributed Oblivious P2P Protocol

OblivP2P-1 Protocol

Naïve approach: Removing Bottleneck

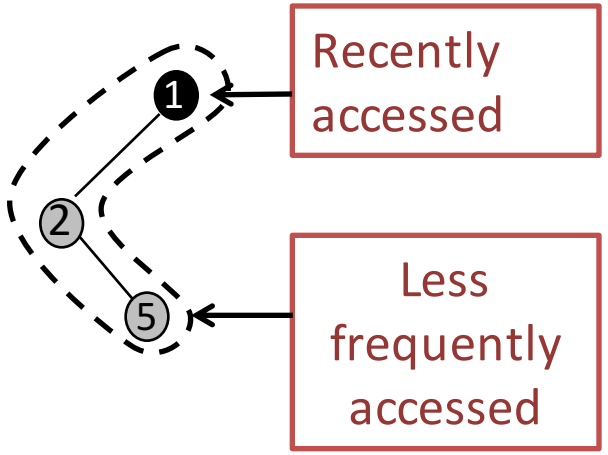
Performance

Security



Challenges

- ORAM writes
  - Recently accessed block at the root
  - Less frequently accessed block at the leaves



- *"Block History"*
  - Shared resources

- Security flaw in P2P systems
  - Multiple users access the same resource

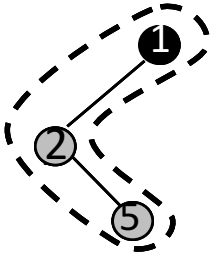
New Primitive: Oblivious Selection

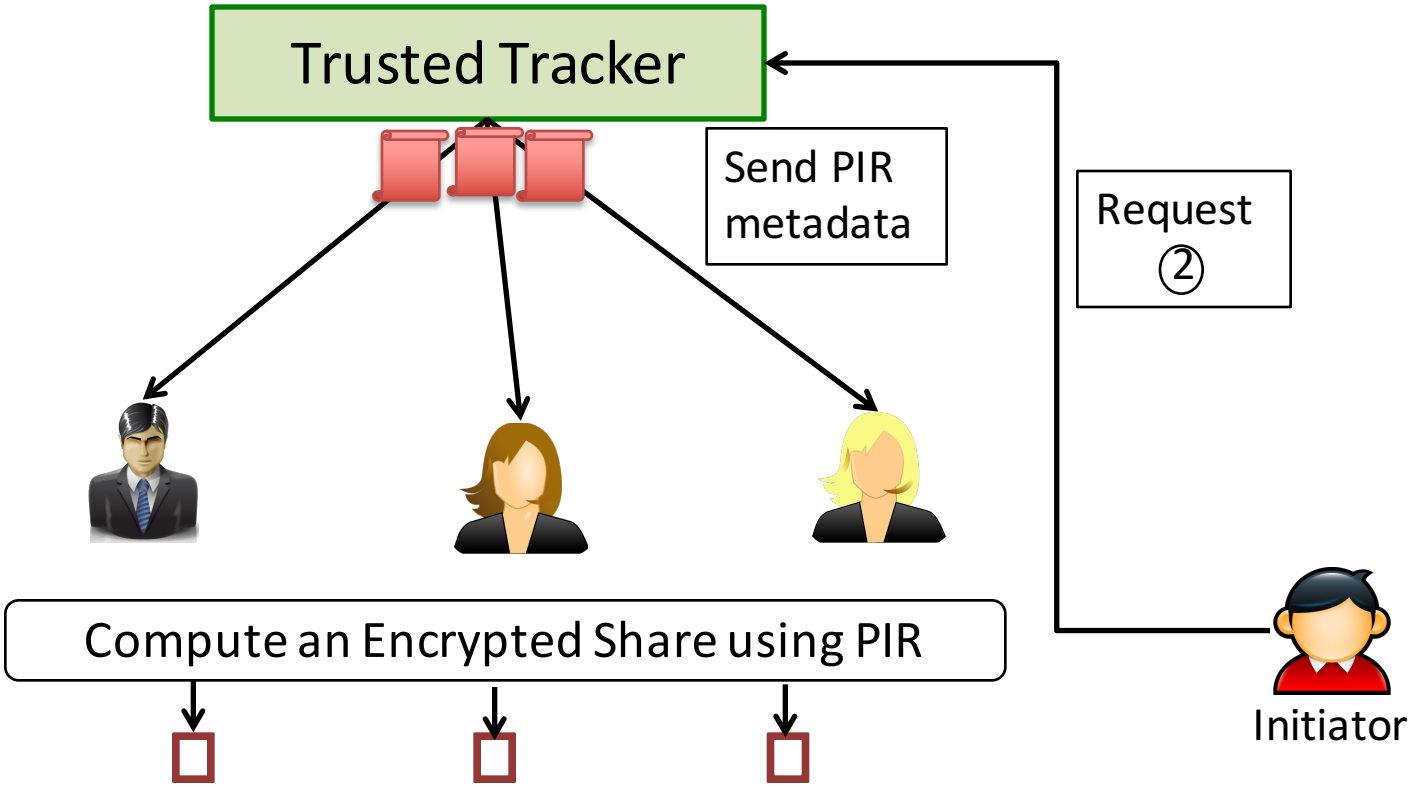
Selects a block *without* :

- Block Position
- Cryptographic Key
- No Centralized Bottleneck

Construction

- Step 1: PIR over ORAM
  - Obliviously select a block from a path





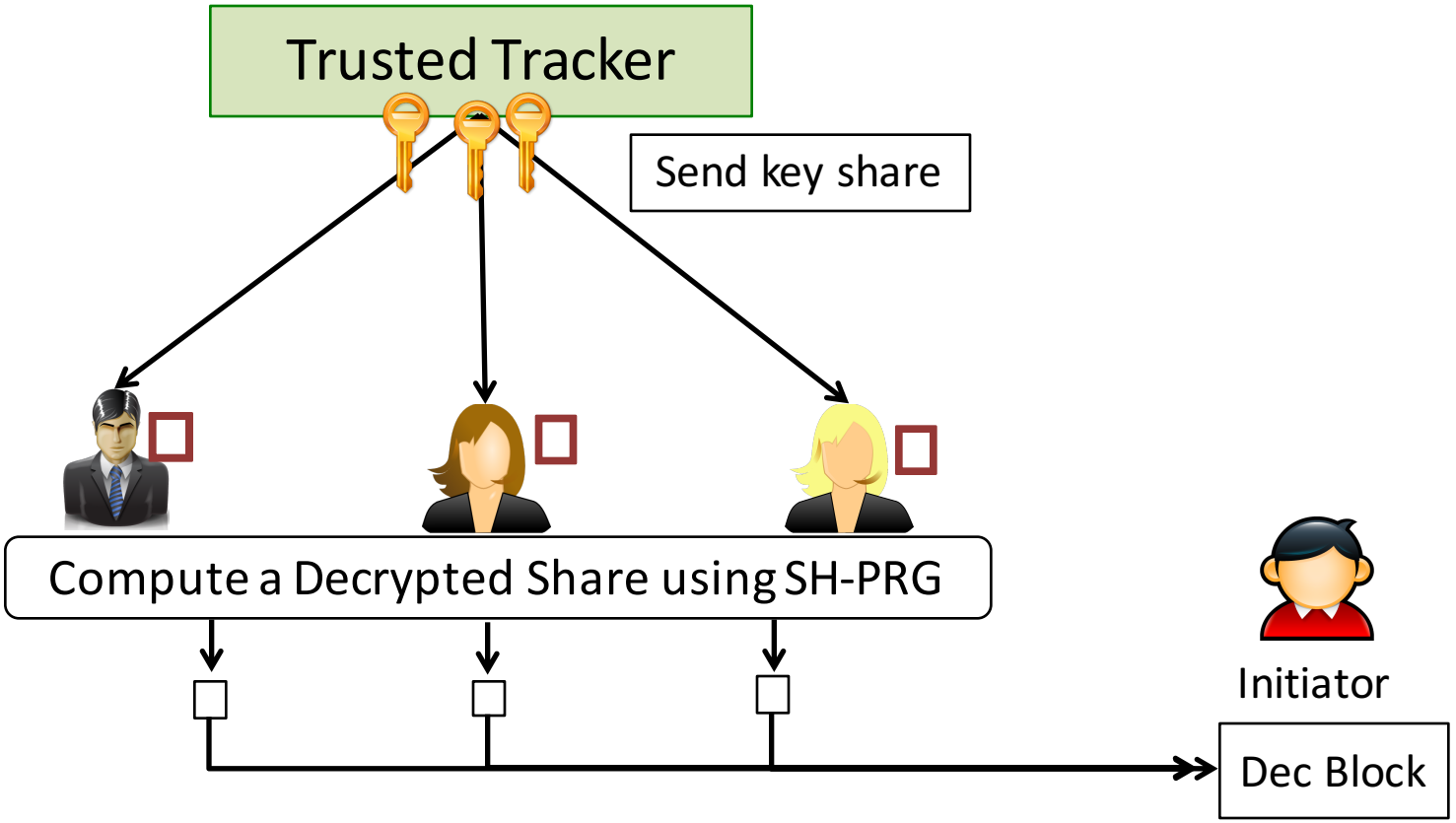
Block Position

Cryptographic Key

No Centralized Bottleneck

Construction

- Step 2: Seed-Homomorphic PRG
  - Decrypt shares without giving away the key



Block Position

Cryptographic Key

No Centralized Bottleneck

Security

OblivP2P is an Oblivious P2P Protocol

Any two equal length access sequences by two peers are indistinguishable for any p.p.t. "honest-but-curious" adversary

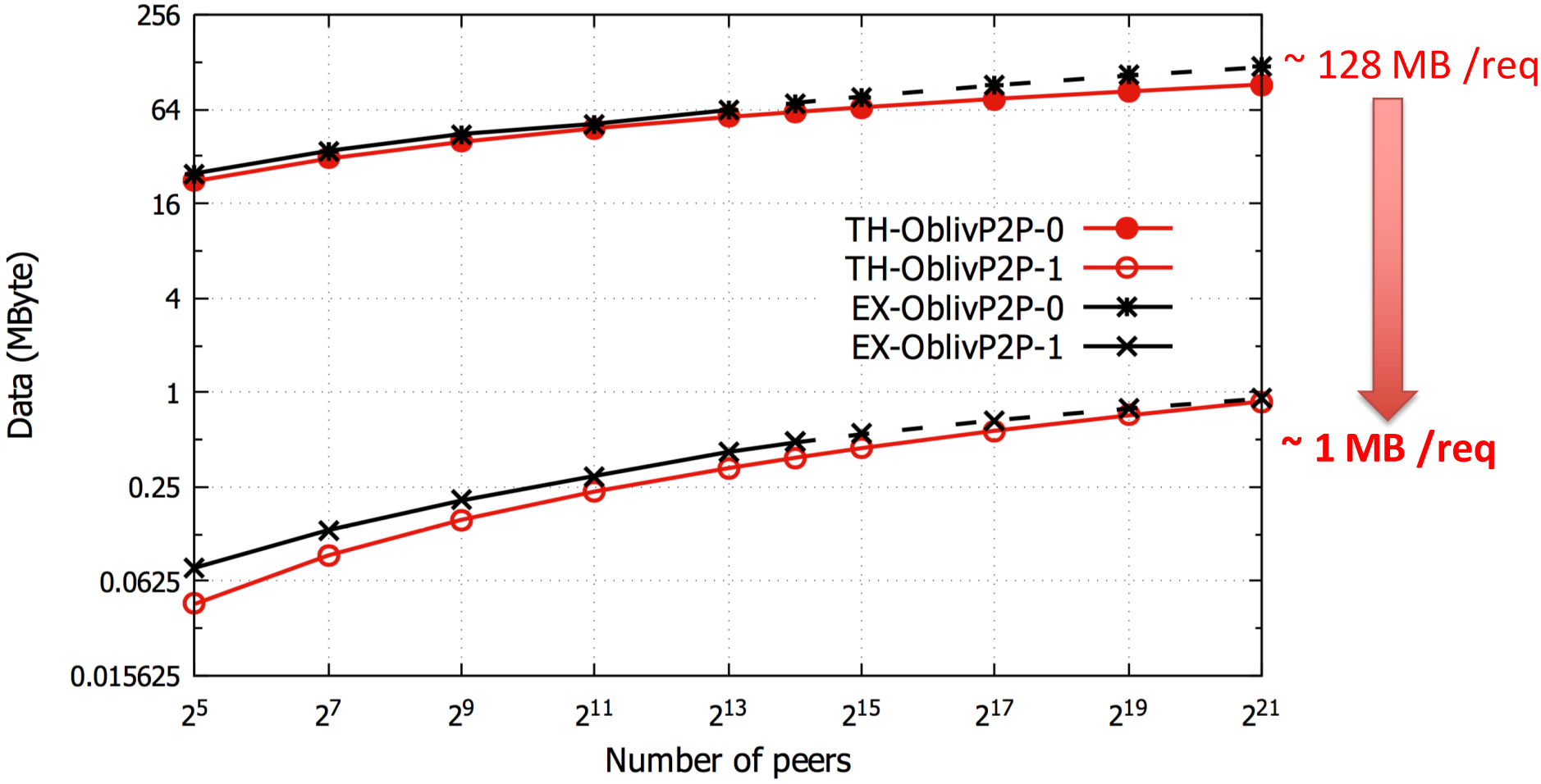
- *Number of dishonest peers is in* $O(N^{\varepsilon})$, *where* $\varepsilon<1$
- *Theorem: If* $\forall N > 1$, *and* $\forall \varepsilon < 1$, $\exists m > 1$ *such that* $2^{\log N \cdot m \cdot (1-\varepsilon)} \in \text{negl}(\lambda)$ *then* OBLIVP2P-*1 is an oblivious P2P protocol*

Evaluation

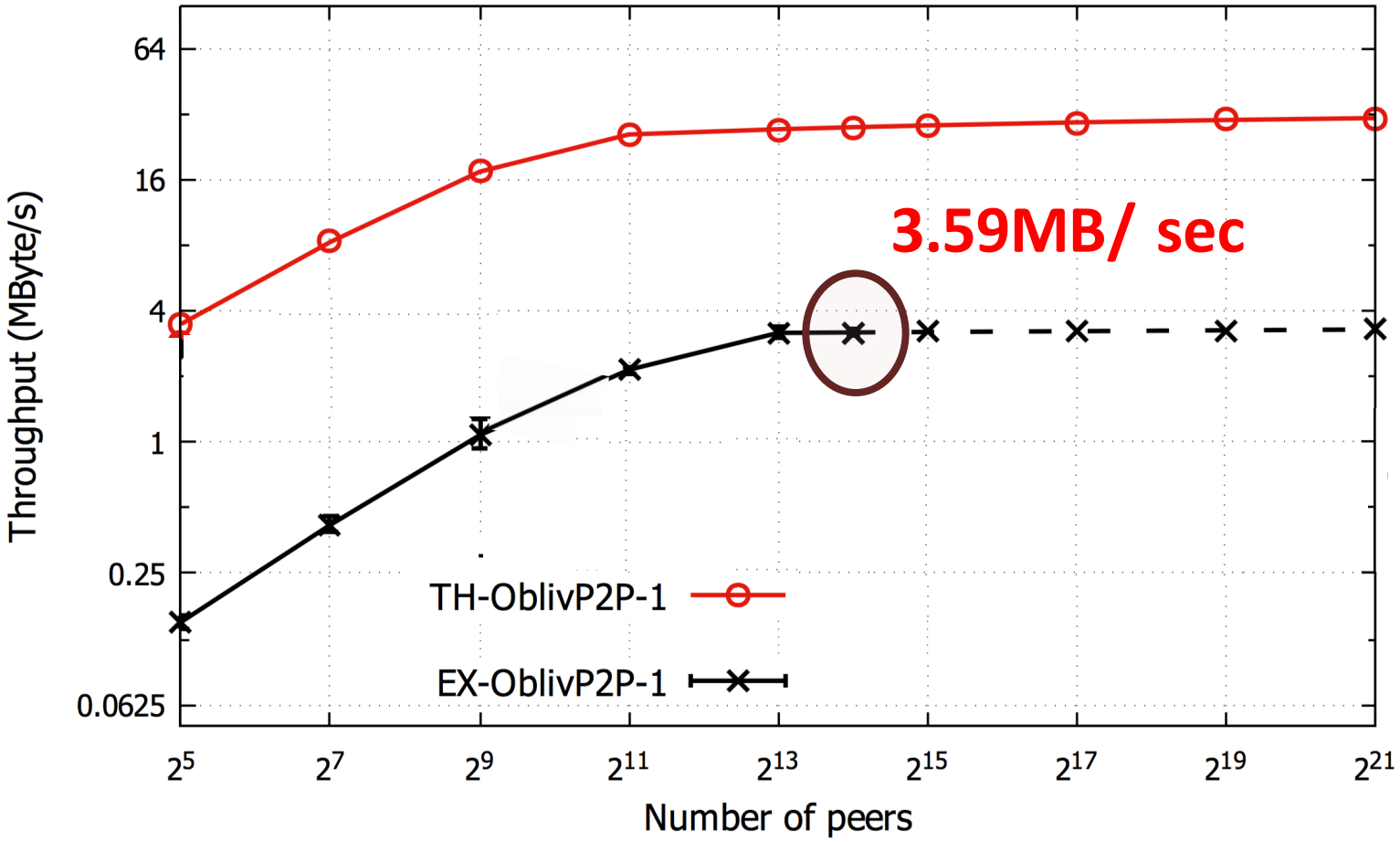
Experimental Setup

- 15 DeterLab servers – (2^{14})16000 peers
- Each server shares a bandwidth of 128 MBps
- Block size of 512 KB similar to BitTorrent

No Centralized Bottleneck



Linear Scalability with Peers



- Larger networks can scale up performance
  - 3.59 MB/s is due to our limited test infrastructure
- Bottleneck remaining is purely computational

Take Away!

- Propose hiding data access patterns in P2P systems
- OblivP2P - First work to repurpose ORAM in Peer-to-Peer systems
- OblivP2P is linearly scalable and highly parallelizable with the peers in the network

Thanks!

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Link: https://github.com/jiayaoqijia/OblivP2P-Code