AUPE:
Collaborative Byzantine fault-tolerant peer-sampling

Compas'25

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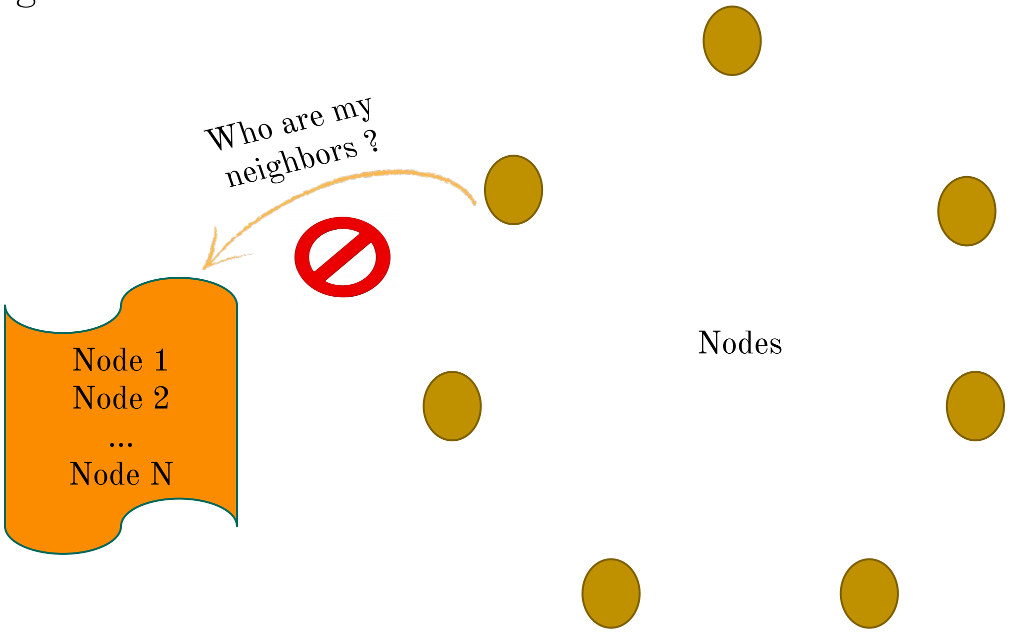
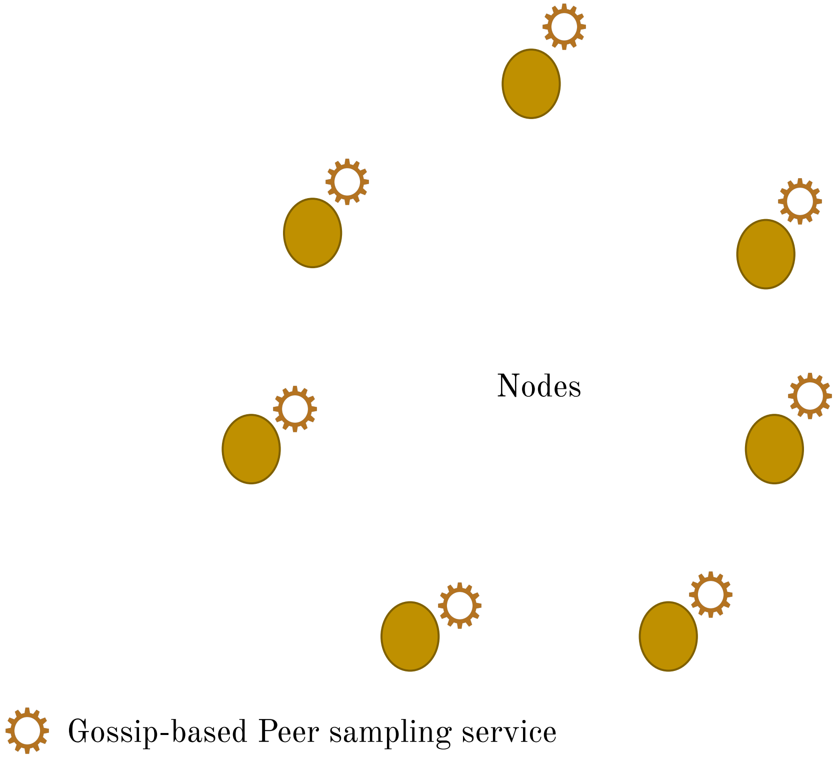
Large scale distributed systems

- No tracking component for neighbors listing



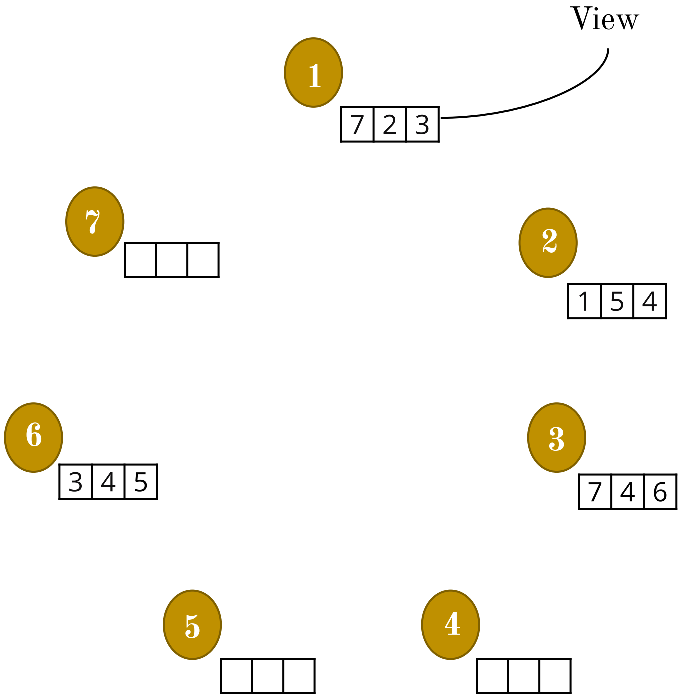
Large scale distributed systems

- **Gossip-based peer sampling**
  - Aim: Maintain knowledge of active nodes
  - For selecting and providing random & uniform samples of identifiers (IDs)



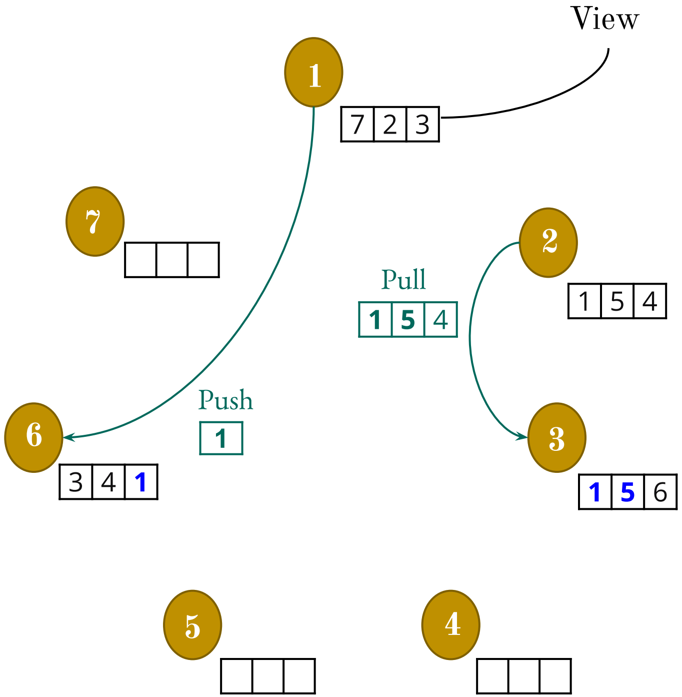
Gossip-based peer sampling service

- Each node has a local **View**



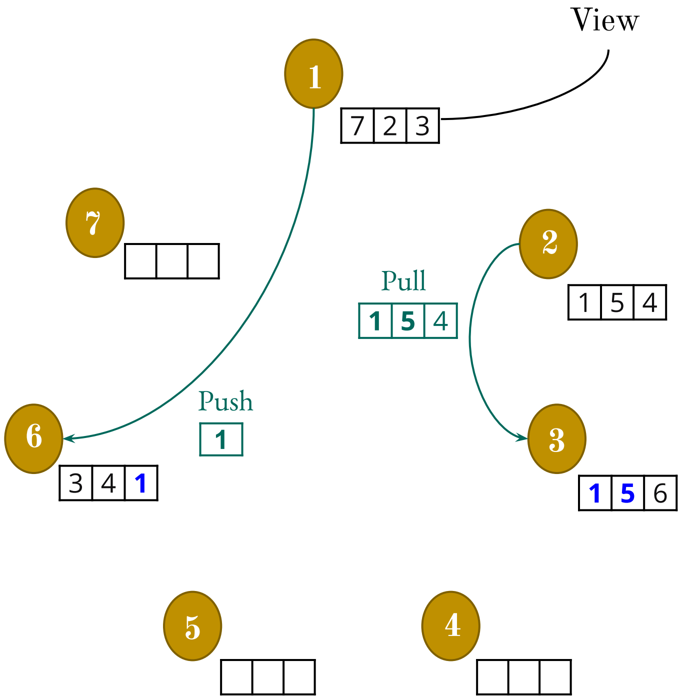
Gossip-based peer sampling service

- Each node has a local **View**
- Periodically:
  - Exchange **Push** and **Pull** requests
  - Update view



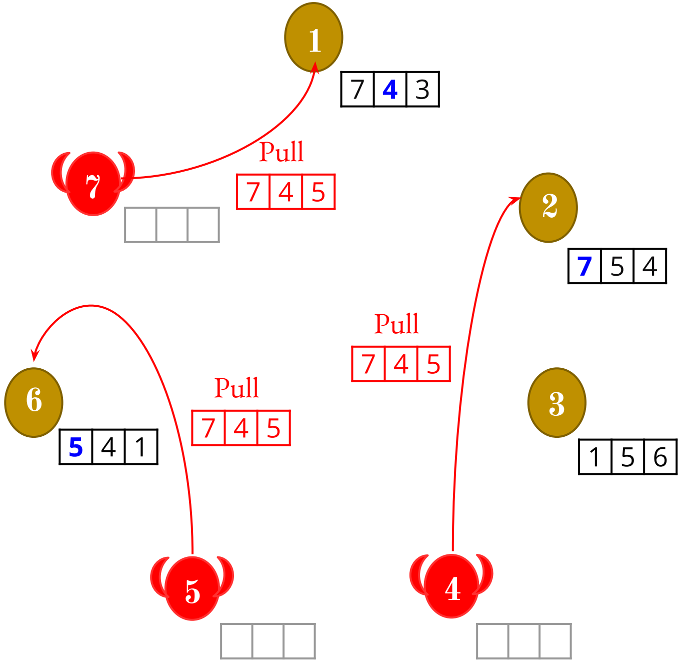
Gossip-based peer sampling service

- Each node has a local **View**
- Periodically:
  - Exchange **Push** and **Pull** requests
  - Update view
- Global network connectivity



Problem

- Group of malicious/Byzantine nodes
- Promote nodes within their member group



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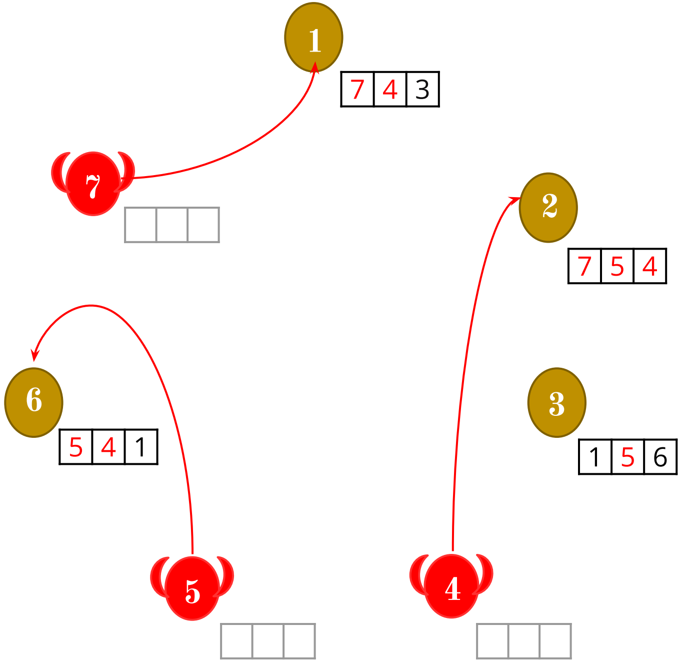
- Increase their representation in honest nodes views



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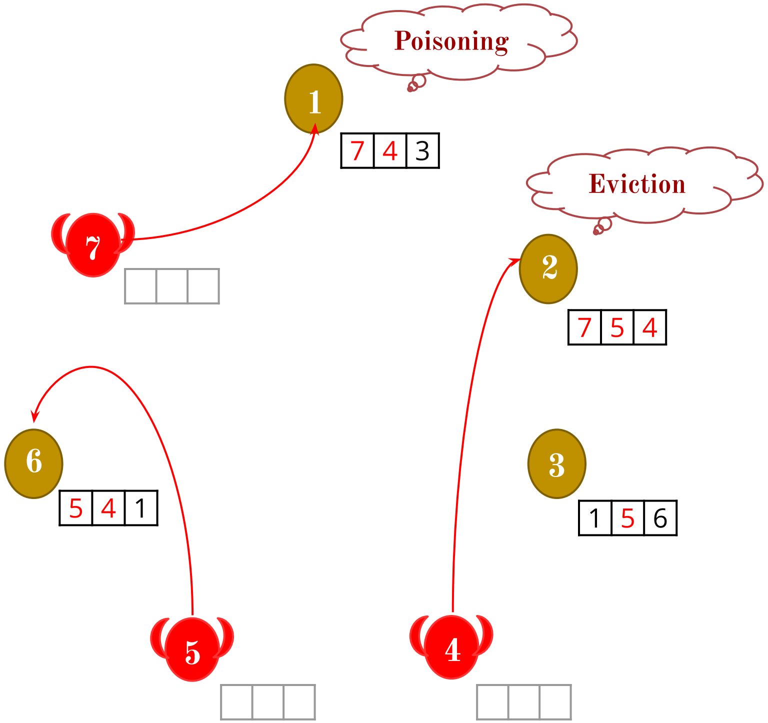

Fault-tolerance

- Tolerate malicious nodes
- Prevent them from polluting the system
- **Brahms,** extension **Basalt**

Fault-tolerance

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Brahms

$f=26\%$ malicious nodes

77% malicious IDs in honest node views

Basalt

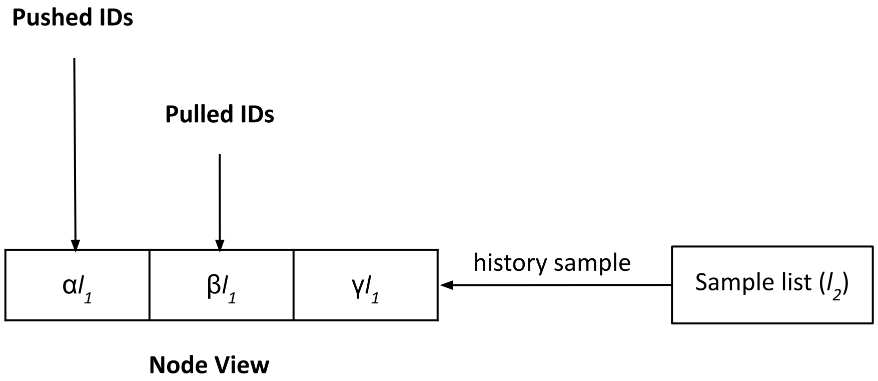
Better than Brahms for **$f< 20\%$**

Results get worse rapidly

BRAHMS overview

Gossip component

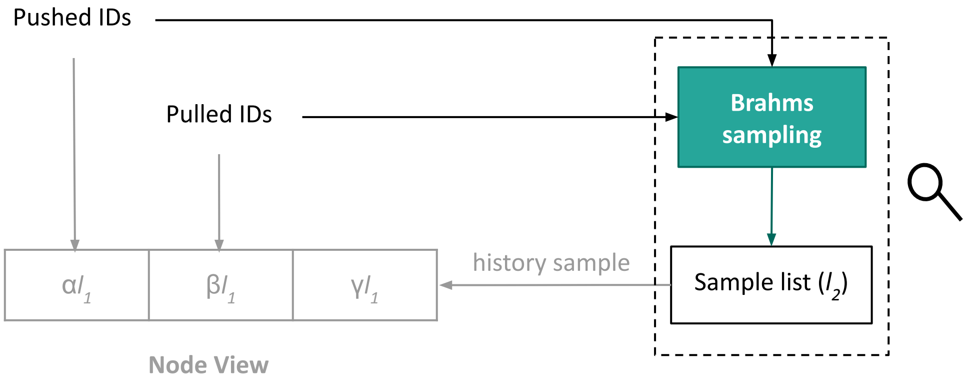
- Handle **push/pull** requests
- View update



BRAHMS overview

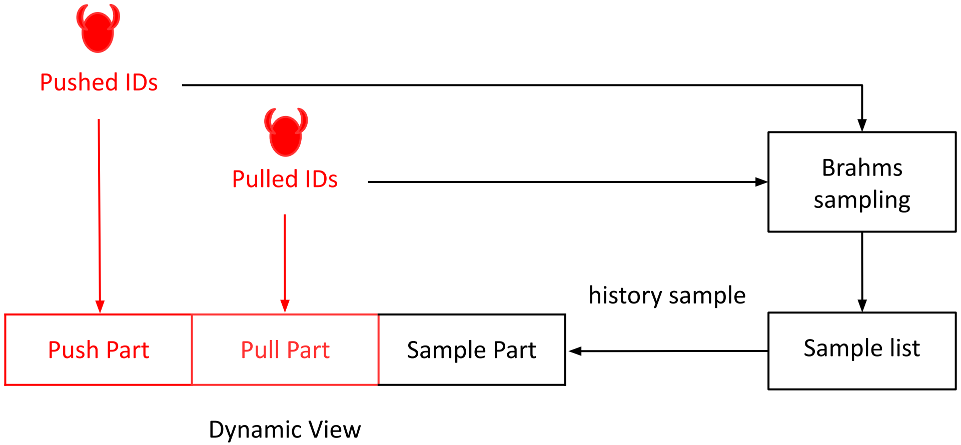
Sampling component

- Set of hash functions
- Uniform sample of seen nodes



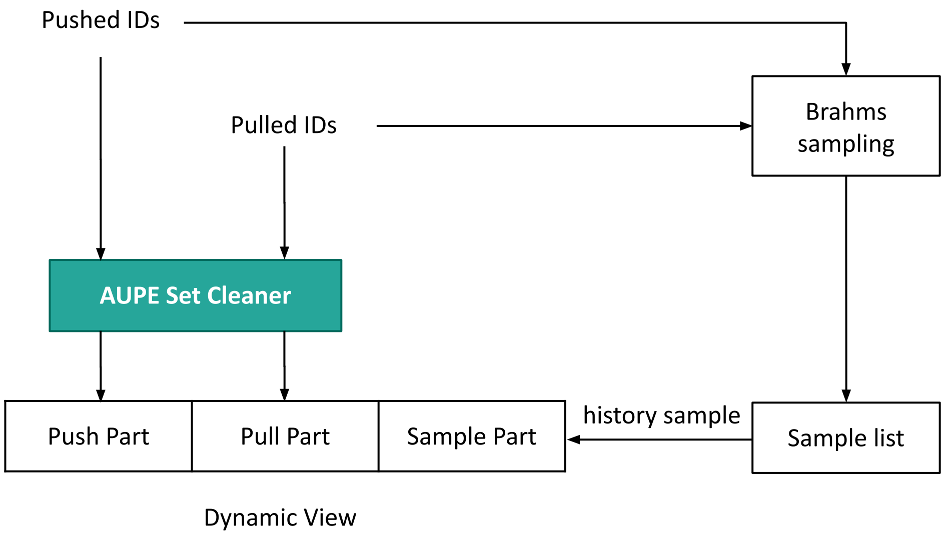
Motivation

- ➔ Received streams of identifiers are source of bias
- ➔ **Mitigate Byzantine over representation inside streams**



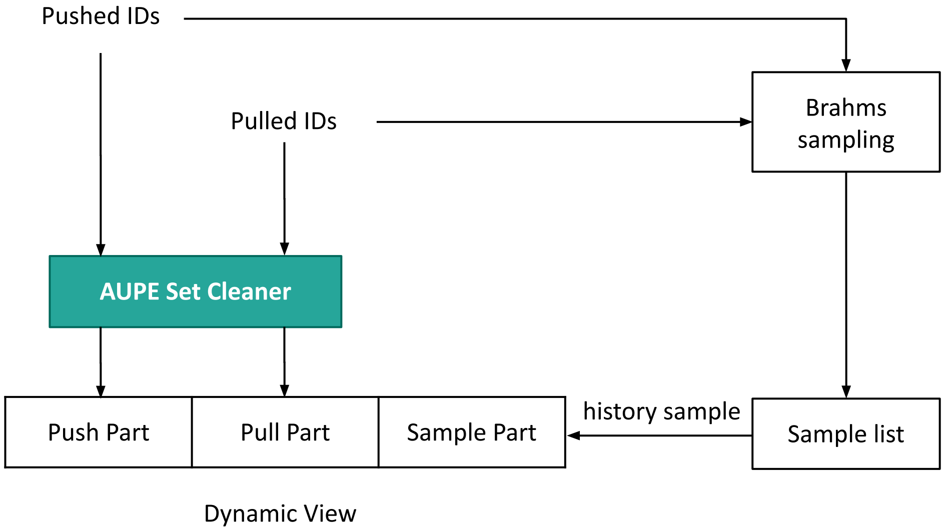
AUPE Protocol

- Based on BRAHMS components
- **AUPE Set Cleaner**
  - Produces less biased streams



AUPE Protocol

- Based on BRAHMS components
- **AUPE Set Cleaner**
    - Produces less biased streams
- **AUPE Secret Collaborative debiasing**
    - Enhance the local debiasing mechanism



AUPE Set Cleaner 🧹

Tracking component

- Record occurrences of received IDs in a tracking data-structure

AUPE Set Cleaner

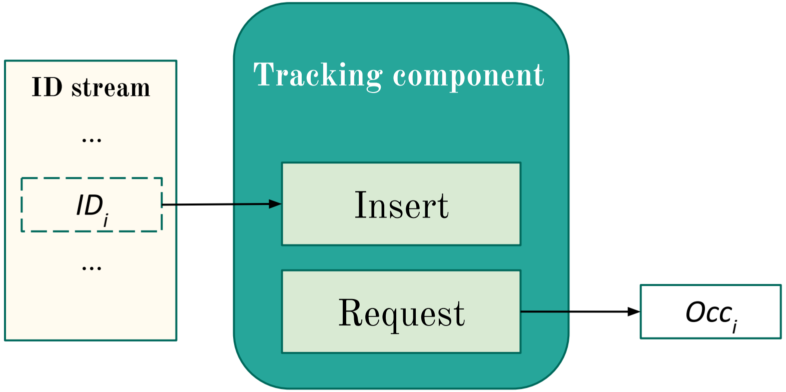
Tracking component

- Record occurrences of received IDs in a tracking data-structure
  - **Key-value store**
  - **Sketch:** Fixed-size data-structure for estimating occurrences

AUPE Set Cleaner

Tracking component

- **Insert** received Ids
- **Request** Id occurrence



Occurrence of node i (real or estimated): Occ_i

AUPE Set Cleaner

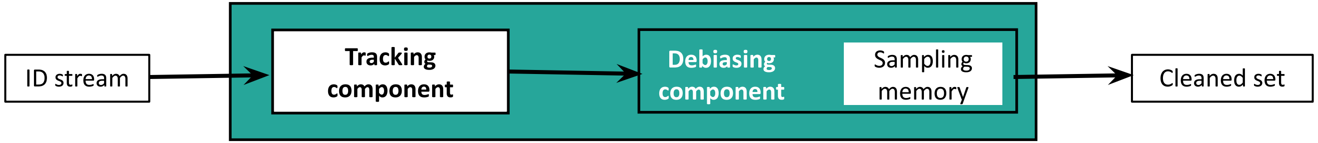
Debiasing component

- Transforms received stream into a more uniform one
- Probability of inserting each item

Probability of insertion of item i : P_i
Minimum of all occurrences : min
Outputed occurrence of node i : Occ_i

$$p_i = \frac{min}{Occ_i}$$

AUPE Set Cleaner review



Increase of Brahms tolerance by up to 60%

AUPE Secret Collaborative Debiasing 🤝

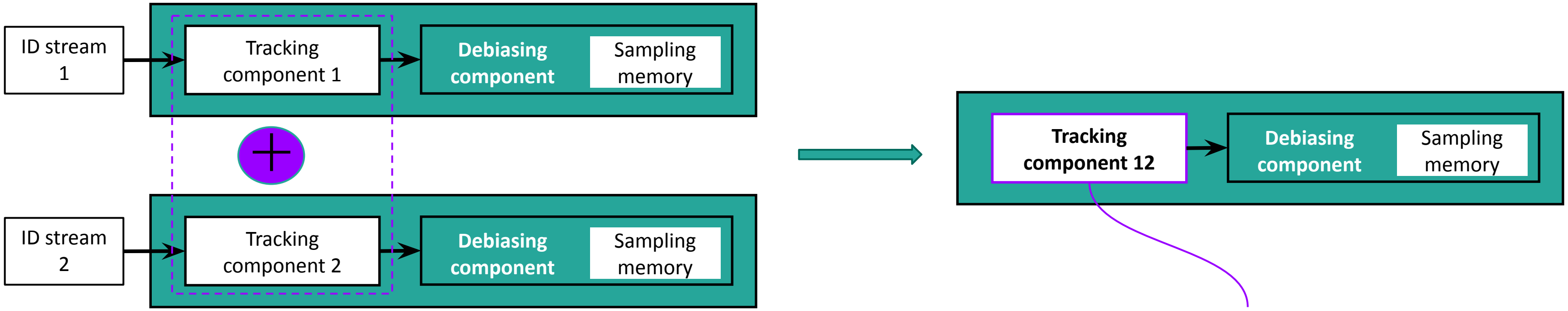
- System is equipped with **Trusted nodes**
  - Based on TEE technology: authenticity of the code
  - **Secure mutual authentication** to recognize trusted peers

AUPE Secret Collaborative Debiasing 🤝

- System is equipped with **Trusted nodes**
  - Based on TEE technology: authenticity of the code
  - **Secure mutual authentication** to recognize trusted peers
- **Exchange** and **merge** their tracking components
- Enhance the debiasing mechanism of the Set Cleaner

AUPE Secret Collaborative Debiasing 🤝

- **Merge** ⊕ : of two tracking components
  - **Average** computation of each corresponding entries



Combined knowledge of streams 1 and 2

AUPE Secret Collaborative Debiasing 🤝

- **Trusted peer list**
  - Last known trusted peer IDs to recontact

Evaluation questions

- To what extent does **Aupe-simple** (without Merge) improve the tolerance ?
- What is the impact of the **secret collaborative debiasing** (Merge)?
- Compare to **Brahms**, **Basalt**

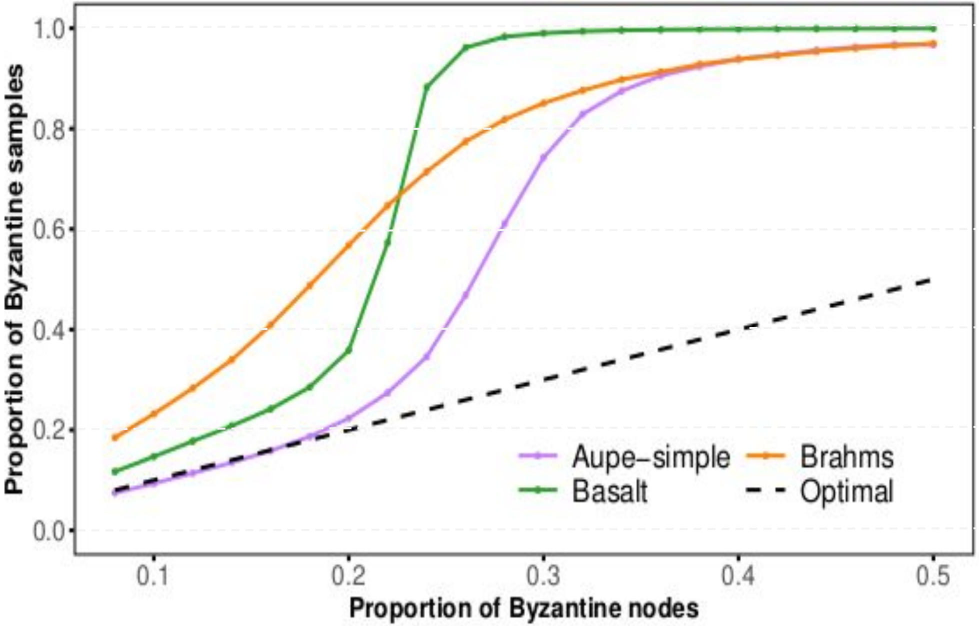
Experimental evaluation

Metric

- **Resilience:** proportion of Byzantine IDs in honest node views at last round
- **Optimal Case:** system resilience is equal to system proportion of Byzantine nodes

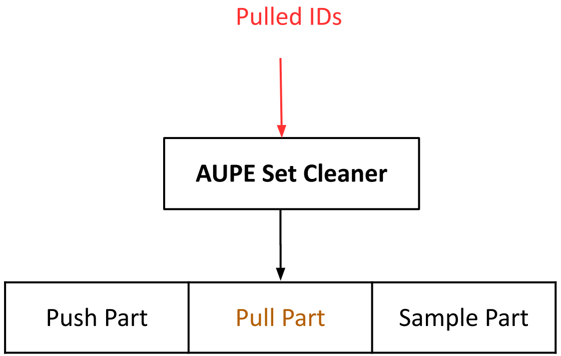
System Tolerance improvement

Aupe-simple

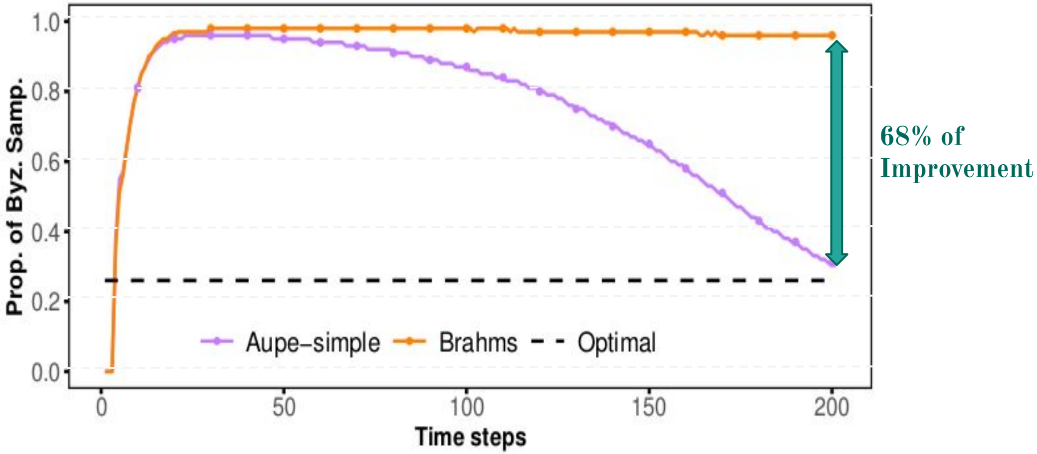


View parts tolerance improvement

Aupe-simple



f=26%

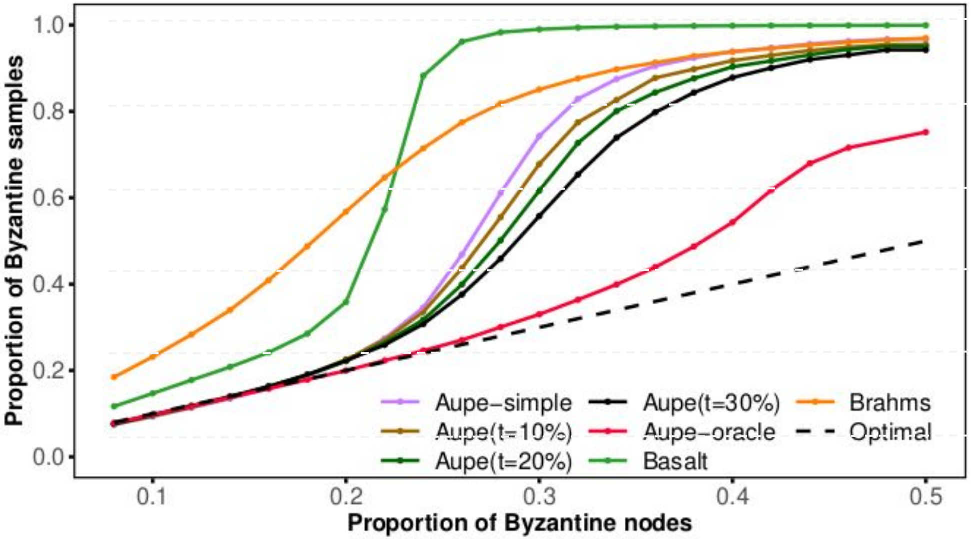


View' Pull part

Collaborative debiasing

Aupe with t=10%, 20% and 30%

- Good impact of collaborative debiasing



Conclusion

- **AUPE**
  - The first peer sampling that utilizes **Collaborative trusted debiasing** to achieve Byzantine-tolerance
- Near-perfect resilience
  - Even with adversary controlling **26%** of nodes

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