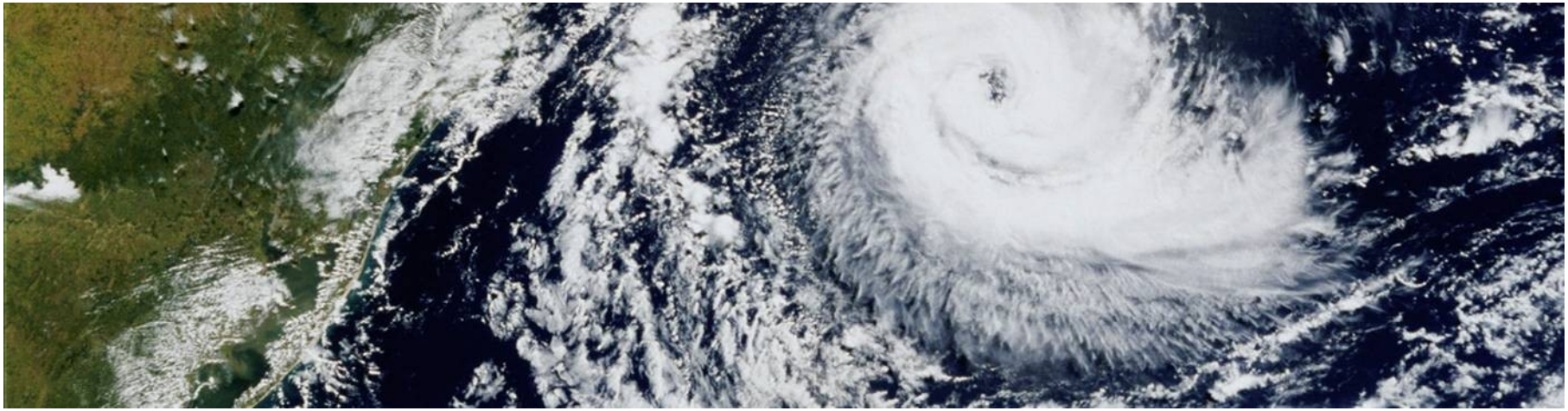
IBM Research – Zurich
Christian Cachin
28 May 2013

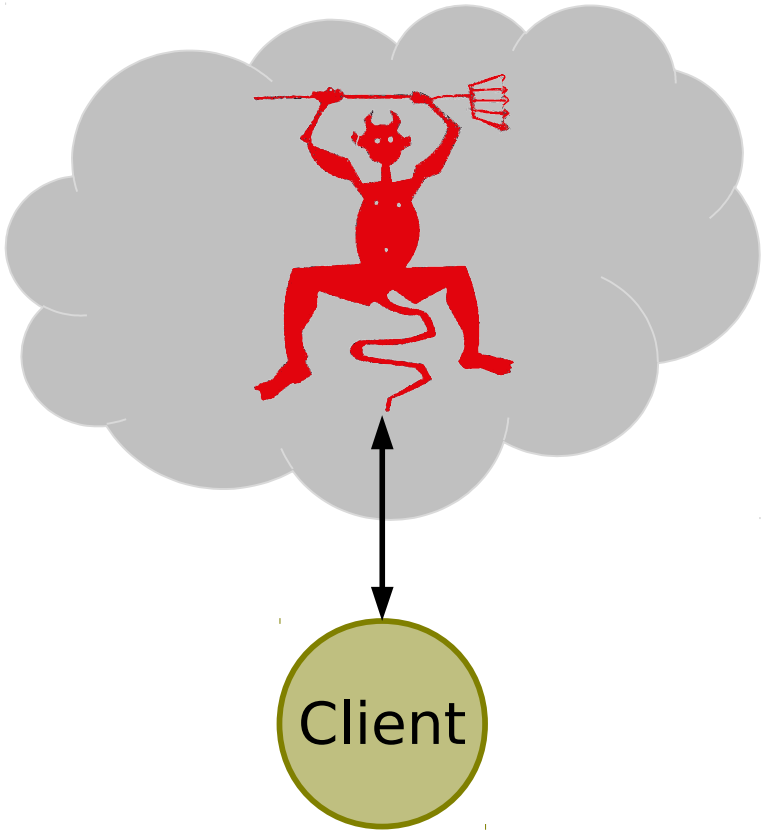
Verifiable Computation with Multiple Clients



Many current results on verifying outsourced computation

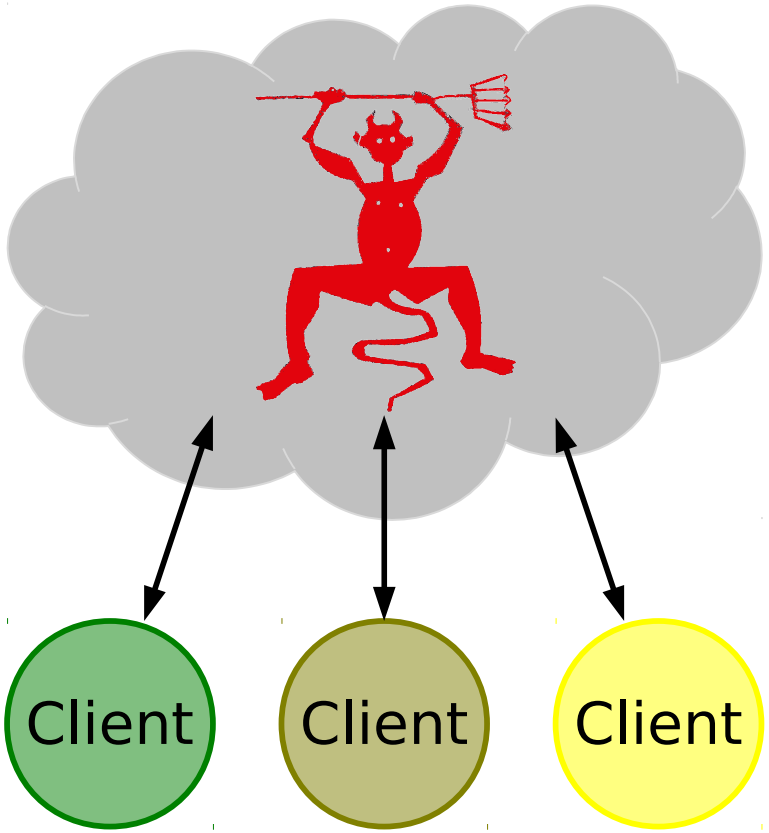
- This Eurocrypt
  - Streaming Authenticated Data Structures
  - Quadratic Span Programs and Succinct NIZKs without PCPs
  - Dynamic Proofs of Retrievability via Oblivious RAM
- Recent
  - Pinocchio: Nearly practical verifiable computation (IEEE S&P '13)
  - A Hybrid Architecture for Interactive Verifiable Computation (IEEE S&P '13)
  - Resolving the conflict between generality and plausibility in verified computation (Eurosys '13)
  - Taking proof-based verified computation a few steps closer to practicality (Usenix Sec '12)
  - Non-interactive verifiable computing: Outsourcing computation to untrusted workers (CRYPTO '10)

Typical model for verifying outsourced computation



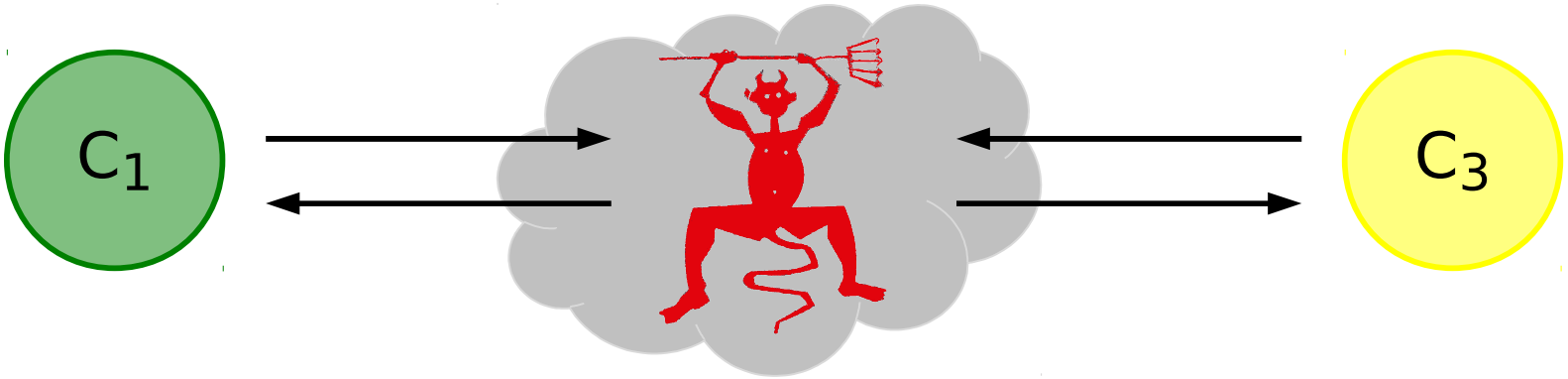
- Server S
  - Normally correct
  - Sometimes faulty (untrusted, potentially malicious ... Byzantine)
- One client C

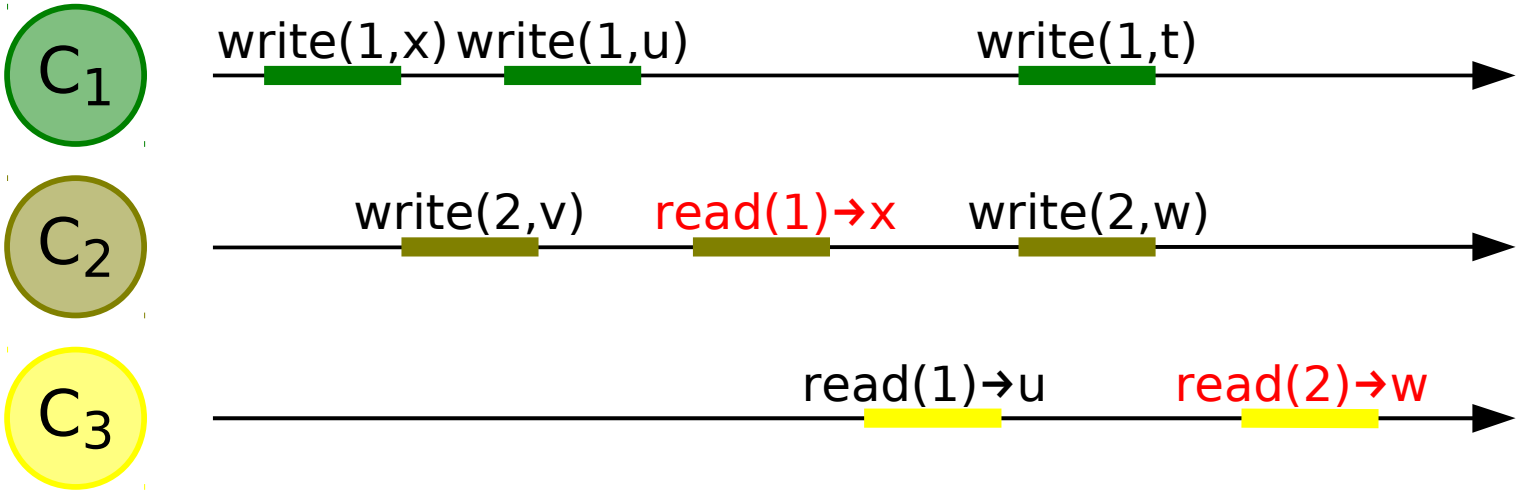
System model



- Server S
  - Normally correct
  - Sometimes faulty (untrusted, potentially malicious ... Byzantine)
- Many clients: C_1 ... C_n
  - Correct, may crash
  - Invoke operations on server
  - Disconnected
  - Small trusted memory
- Asynchronous
- No client-client communication

Integrity violation from replay attack

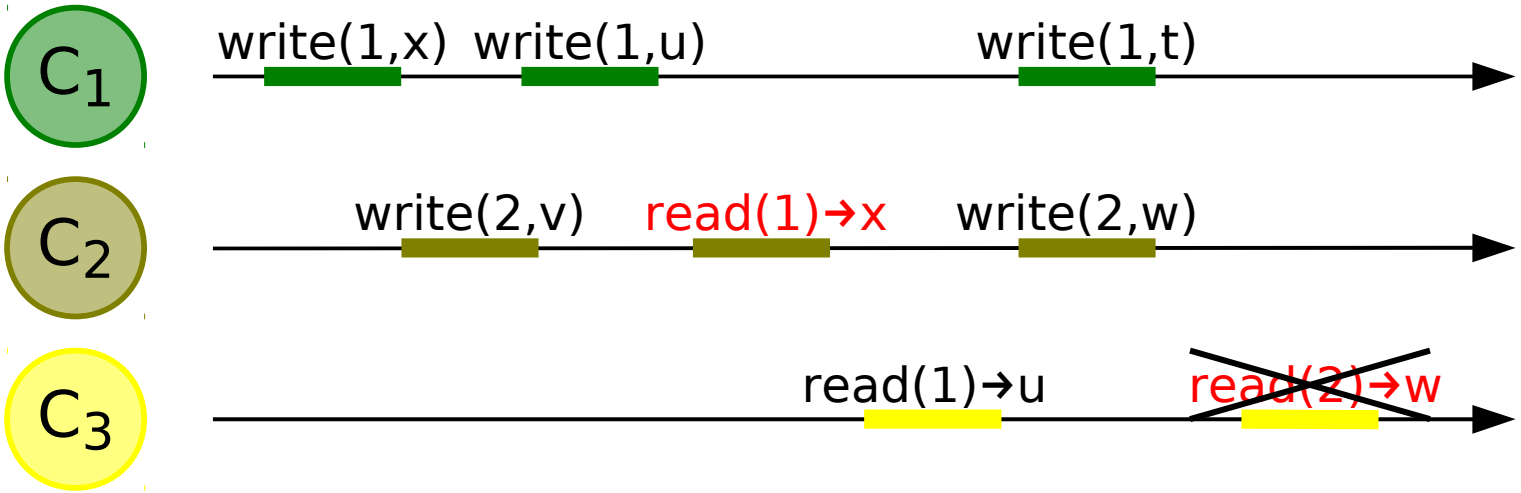


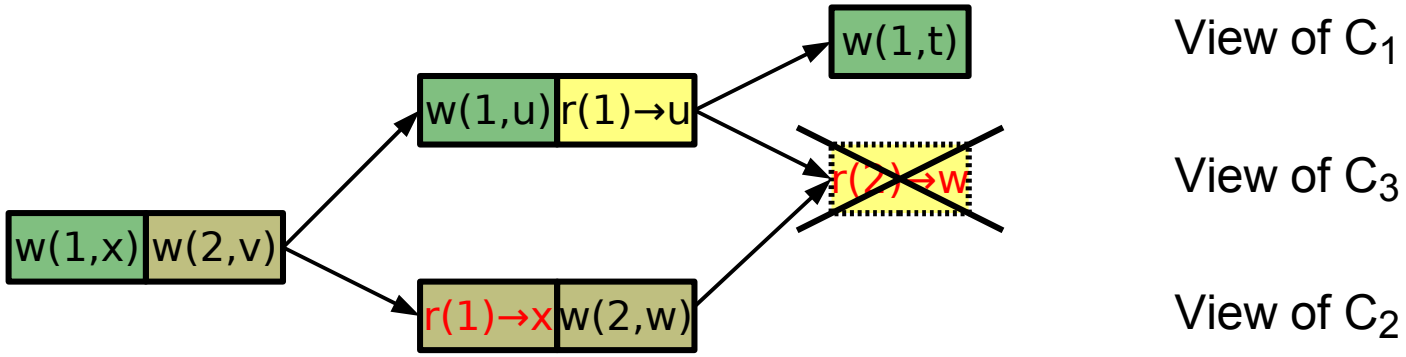


From replay attacks to fork-linearizability

- In replay attack, server may present different views to clients
  - Cannot be detected by clients
  - Server "forks" the views of different clients
- Run a protocol to impose fork linearizability [MS02]
  - Ensures that if server forks the views of two clients once, then
    → their views are forked ever after
    → they never again see each others updates
- Every consistency or integrity violation results in a fork
  - Best achievable guarantee for interaction with untrusted server
- Forks can be detected on a cheap external channel with low security
  - Synchronized clocks
  - Periodic operations
  - Gossip

Fork-linearizability graphically





Fork-linearizabile storage and services

- **Goal**
  - If server is correct, then clients see linearizable operations
  - In any case (= even when server corrupted and violates spec), the clients respect fork-linearizability
- **SUNDR** [Mazieres, Shasha, '02]
  - Secure untrusted data repository (storage system)
- **FAUST - Fail-aware untrusted storage** [CKS11]
  - Never blocks, uses sporadic client-to-client messages
- **Blind Stone Tablet** [Williams, Sion, Shasha, '09]
  - Never blocks, but may abort operations (databases)
- **Untrusted Services** [C11]
  - Generic protocol using ideas from authenticated data types
  - Blocking
- **Non-blocking Commutative-Operation Verification** [CO13]
  - Generic services, but operations verified by re-execution
  - Non-blocking for commuting operations

Conclusion

- **Existing work**
  - Storage-integrity verification protocols, simple functionality
  - Integrity and consistency verification protocols, but without efficient cryptographic verification
  - Cryptographic verification protocols, only for single-client model
- **Challenge**

  Build cryptographic tools for integrity and consistency verification
  - **Stateful remote services**
  - **Preserve "forking" consistency notions**
  - **Non-blocking client operations**

Literature

[CO13] C. Cachin and O. Ohrimenko, "On verifying the consistency of remote untrusted services," arXiv:1302.4808 [cs.DC], 2013.

[C11] C. Cachin, "Integrity and consistency for untrusted services," in Proc. Current Trends in Theory and Practice of Computer Science (SOFSEM 2011), LNCS 6543, 2011.

[CKS11] C. Cachin, I. Keidar, and A. Shraer, "Fail-aware untrusted storage," SIAM Journal on Computing, vol. 40, Apr. 2011.