Remote Data Checking: Auditing the Preservation Status of Massive Data Sets on Untrusted Stores

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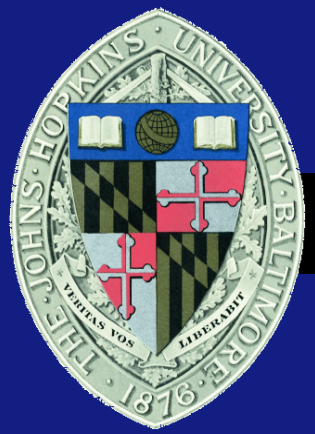

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What's Remote Data Checking?

Auditing protocols that verify the correctness of data objects on remote, untrusted stores

- Without transferring data to the client
  - Constant network complexity per audit per object
  - Constant amount of metadata per object
- That do not require the store to access the entire file
  - Constant amount of I/O per audit per object

Service-Oriented Architectures

- Outsourced storage commoditized and ubiquitous
  - Cloud computing
  - Amazon S3/EC
  - SDSC Storage Resource Broker
- And, the associated security problems
  - How much trust must we place in services?
  - For data, auditing services for correctness, availability, preservation

Why Remote Data Checking?

- Verifying integrity/content on retrieval is insufficient
  - Too late, data are already damaged.
  - Identifying damaged data quickly is critical to repair
- Data are too large to retrieve and check
  - I/O burden on servers
  - Lots of network traffic
  - Expensive! Services charge by byte of I/O and byte transferred
- Exposure
  - Data are held for long periods of time
  - Much data are accessed infrequently or never

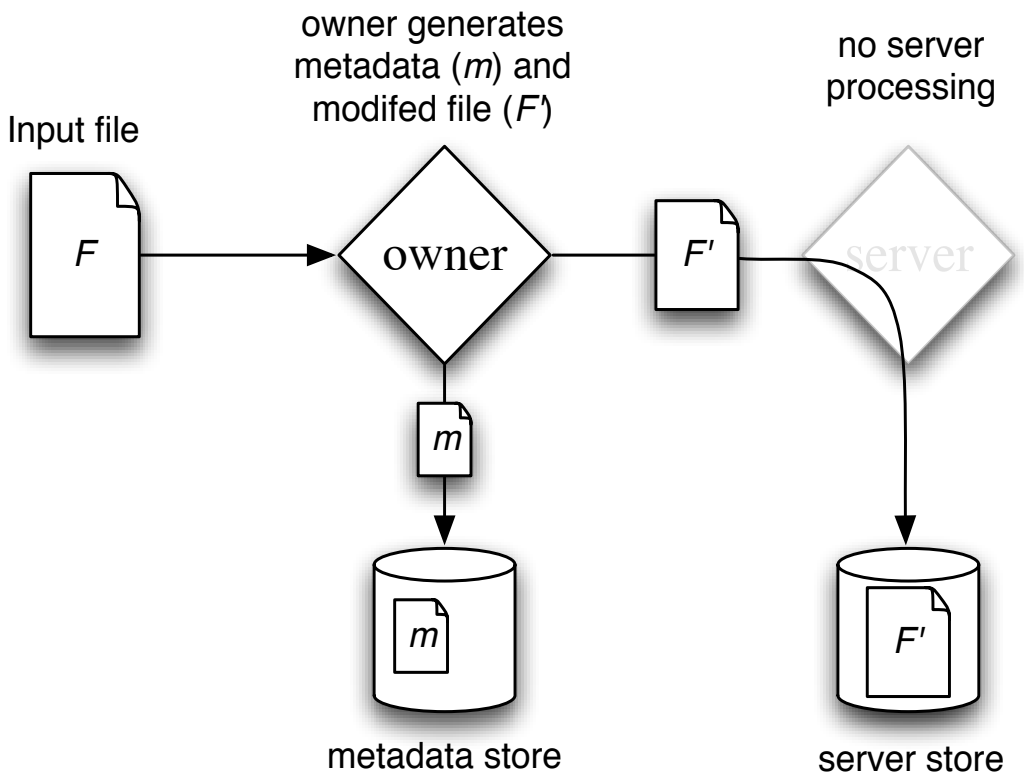
Don't I Trust Service Providers?

- Financial motivations to cheat
  - Charge for terabytes and store gigabytes
  - Discard unaccessed data (based on statistical analysis)
  - Keep fewer replicas than promised
- Reputation
  - Hide data loss incidents
- Latent errors
  - Of which service providers are unaware

- There's a history of data-loss incidents

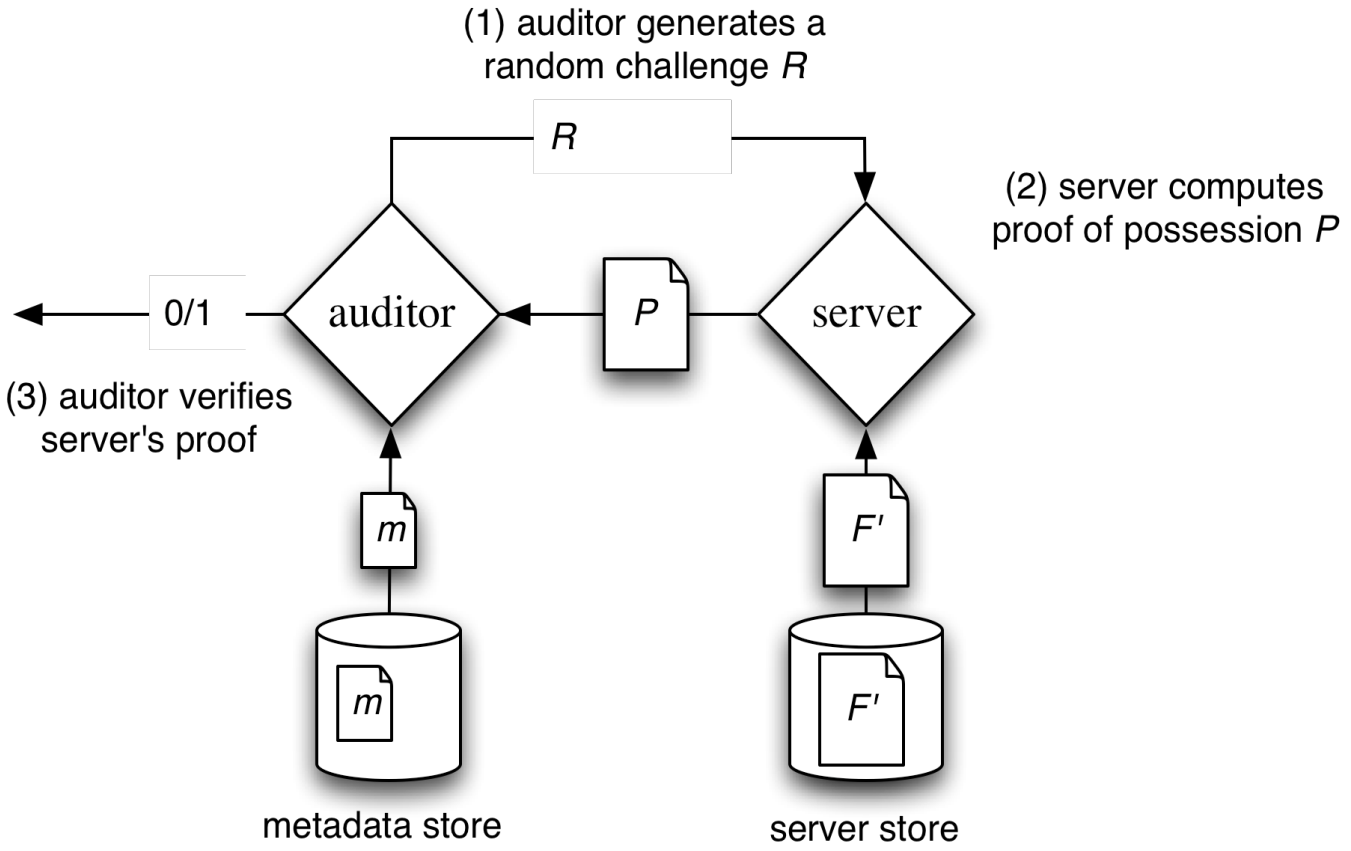
RDC Storage Protocol

- Data owner preprocesses file for RDC protocol
  - May modify file (add bytes, tags, etc.)
  - Generate a constant amount of (public or private) metadata



RDC Audit Protocol

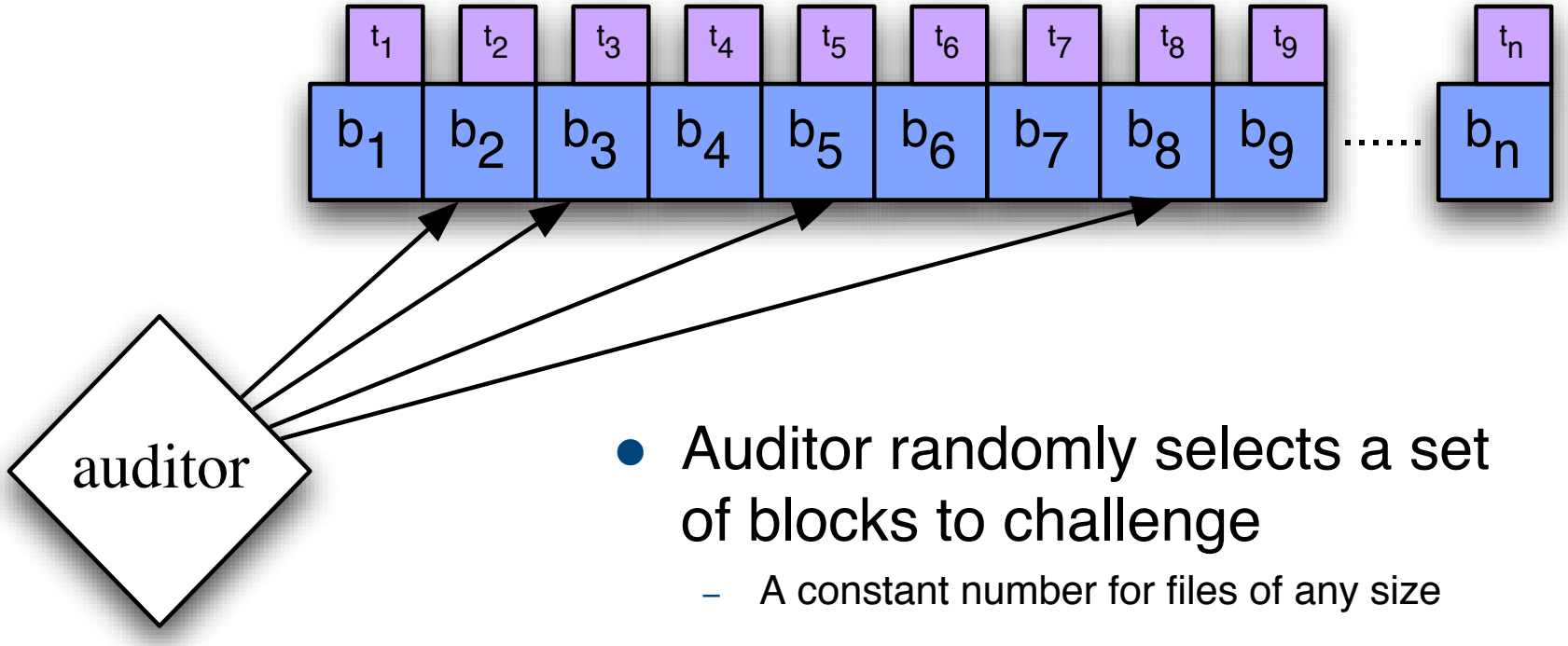
- Verify that an untrusted store retains the correct data
  - Without transferring the data to the verifier (homomorphism)



Many RDC Protocols

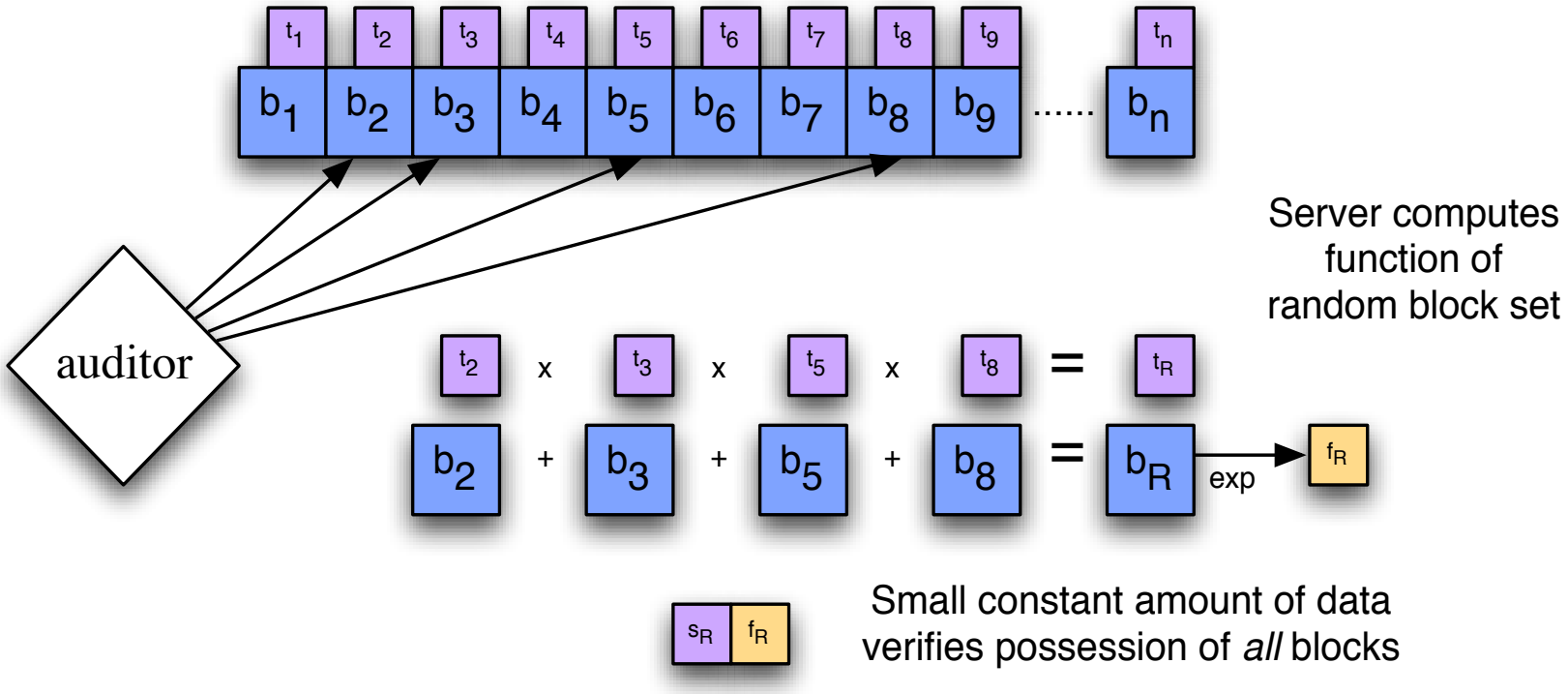
- Hot topic of recent industrial and academic research
  - Security [AB+08, BJO08, SW08]
  - Others that don't quite fit our definition [JK07, KAD07, SM06]
  - Related concepts and extensions [CK+08, CKB08, SS+08]
- Several core principles have emerged
  - Compact signature for multiple blocks: homomorphic tags
  - Probabilistic audits via spot checking
  - Redundancy in storage with forward error correction
- I will explain with Provable Data Possession (PDP)
  - Our system [AB+08, CK+08, CKB08]

PDP's Spot Checking



- Auditor randomly selects a set of blocks to challenge
  - A constant number for files of any size

PDP's Homomorphic Tags



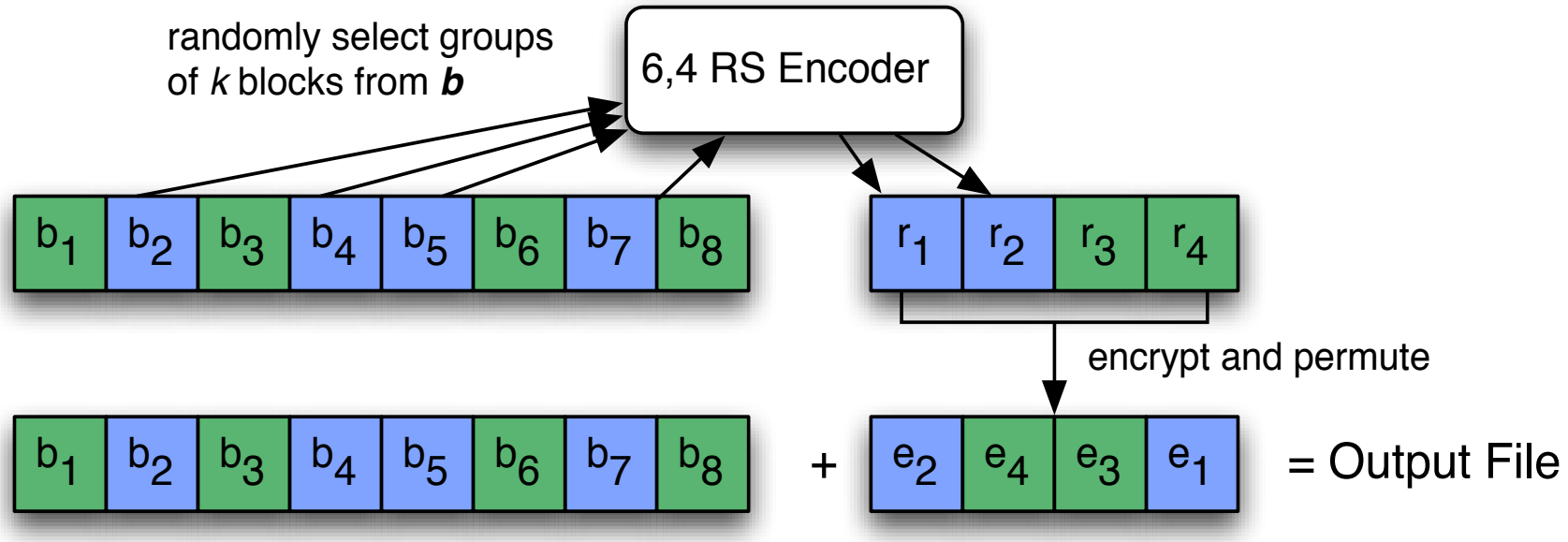
- Server processing is I/O bound
  - Single exponentiation per challenge

Forward Error Correcting (FEC) Codes

- Integrating data checking with redundancy
  - Improves possession guarantee realized from spot checking
- Attacker cannot effectively delete data
  - Big attacks are easy to detect
  - Small attacks are recoverable
- Use systematic codes [BJO08,CKB08]
  - To preserve sequential file layout for read performance

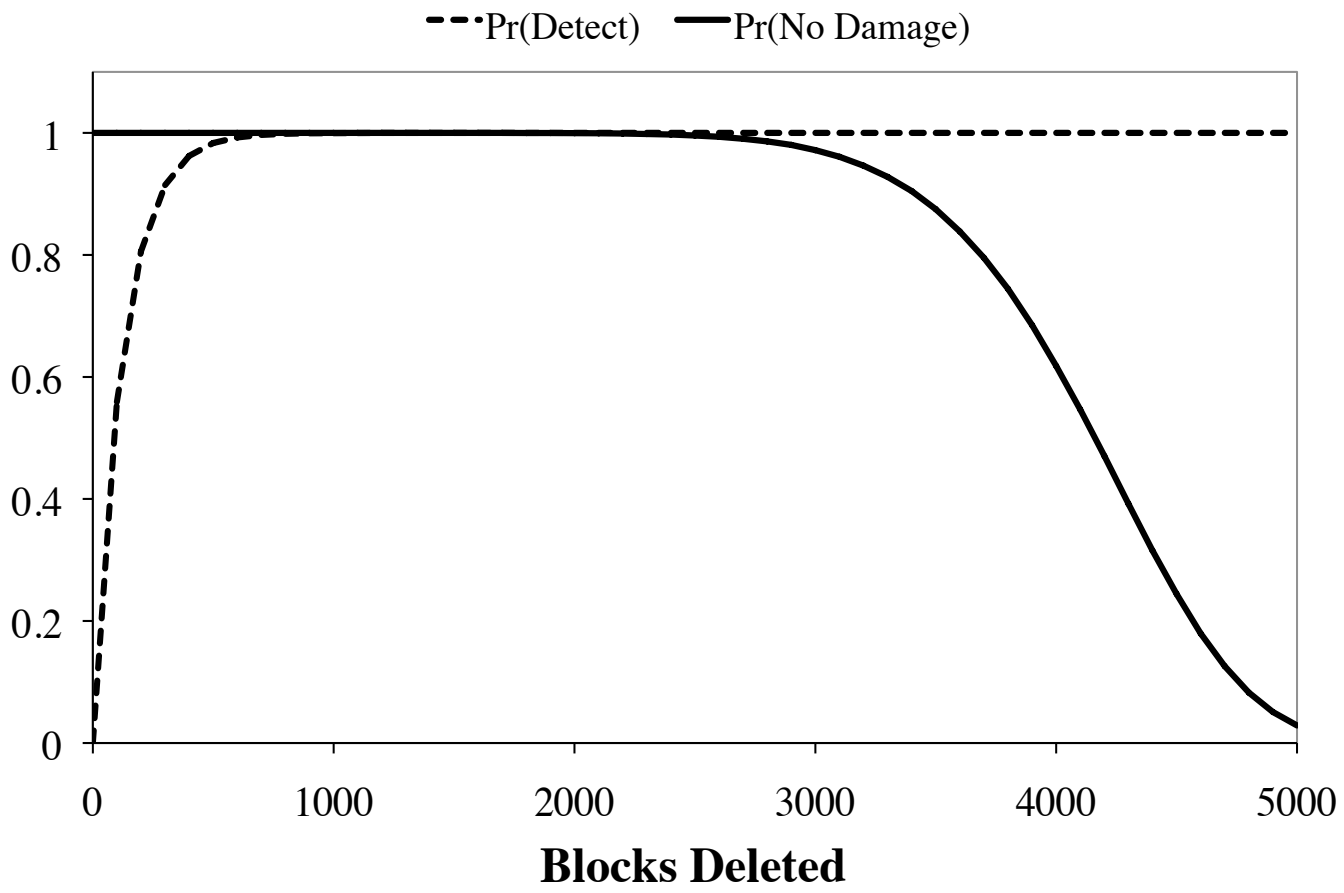
PDP with Reed-Solomon Coding

- Systematic RS code keeps original file sequential
  - Practical RS codes fixed/limited widths
- Layout must conceal coding constraints among blocks
  - Random selection of input blocks
  - Encryption and permutation of redundancy blocks



PDP+FEC: An Attacker's Perspective

- Successful attack probability < 0.00001
  - 10% redundancy, checking 500kb of a 600MB file



Additional Desirable Properties

- Dynamic (or incremental)
  - Can modify file contents without exposure to replay attacks
- Publicly verifiable
  - No secret material needed to conduct audits
- Efficient (for pre-processing files)
  - Auditing is already quite fast (I/O bound)
- Multiple-replica
- Privacy preserving [SS+08]
  - RDC protocol reveals nothing about the content to the verifier

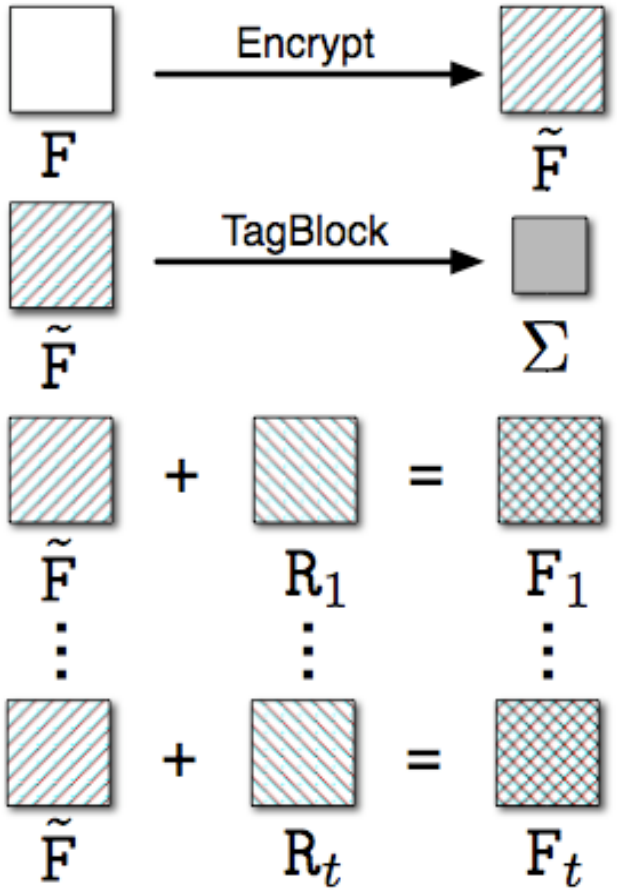
- No single protocol provides all
  - Notably, publicly verifiable conflicts with dynamic and efficient

PDP: Observations about RSA

- Provably secure
- Allows for public-verifiability
  - Anyone can check possession (even if they can't access content)
  - Metadata easy to manage. It's not secret and can be replicated widely or published.
- Supports multi-replica protocols
  - Differentiate copies of the same data in network
  - Dynamic creation of new copies
- Performance limitations for storage
  - Must exponentiate every block: to generate the tag
  - Suitable for archival data (store once)
  - Good audit performance

Multiple-Replica PDP [CB+08]

- Multiple copies in untrusted networks to protect data
- For storing/auditing replicas
  - Ensure system stores *t* unique copies
  - Create new replicas on demand
  - Need efficient techniques to define replicas, i.e. better than PDP *t* times
- MR-PDP (Multiple-replica)
  - All the above and
  - Verify all replicas with single set of signatures, i.e. O(1) metadata



Other Interesting Ideas

- Commitment schemes (Safestore [KAD07])
  - Have a server provide fresh signatures for many files
  - Check a few files among the fresh signatures
  - Spot checking across files can be used in conjunction with RDC
- Symmetric key homomorphisms [MS06,SW08]
  - Makes pre-processing fast
  - Supports dynamic RDC
  - Not publicly verifiable and metadata must be kept secret
- Hierarchical redundancy encoding
  - Split redundancy across multiple servers and within file [KAD07]
  - Use redundancy in challenge protocol and within file [BJO08]

Conclusions

- Remote data checking supports the outsourced storage model of service-oriented architectures
- PDP and other RDC schemes provide secure and efficient (in both I/O and network) auditing
  - We have yet to get all the desirable features in a single system
- Important systems issues remain
  - File layouts and redundancy
  - Distributed implementations
  - Many usable security schemes

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