LINCS: Towards Building a Trustworthy Litigation Hold Enabled Cloud Storage System

Shams Zawoad, Ragib Hasan, and John Grimes

University of Alabama at Birmingham, Alabama, USA

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Department of CIS, UAB
http://secret.cis.uab.edu

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Outline

- Background
  - Litigation Hold | Spoliation | Model
- Motivation
  - Case Study | Current Solution | Research Gap
- Litigation hold enabled Cloud Storage (**LINCS**) system
  - Threat Model| Protocol| Security | Results | Tool
- Conclusion & Future Work

Background | Litigation Hold

- Legal notice to a defendant that triggers the preservation of ESI
- Preservation obligation comes from common law, statutes, regulations, or a court order

Litigation holds in the cloud

- Defendant's data is now under the direct control of a third party

Background | Spoliation

- Deliberate destruction or modification of ESI by a litigant party
- Defendant produces proof of preservation of litigation hold
- Plaintiff provides the evidence of spoliation
- Can cost reputation, fines, penalties, etc.

Background | Litigation Hold Model

T_s: Litigation hold is issued

T_e: Litigation hold ends

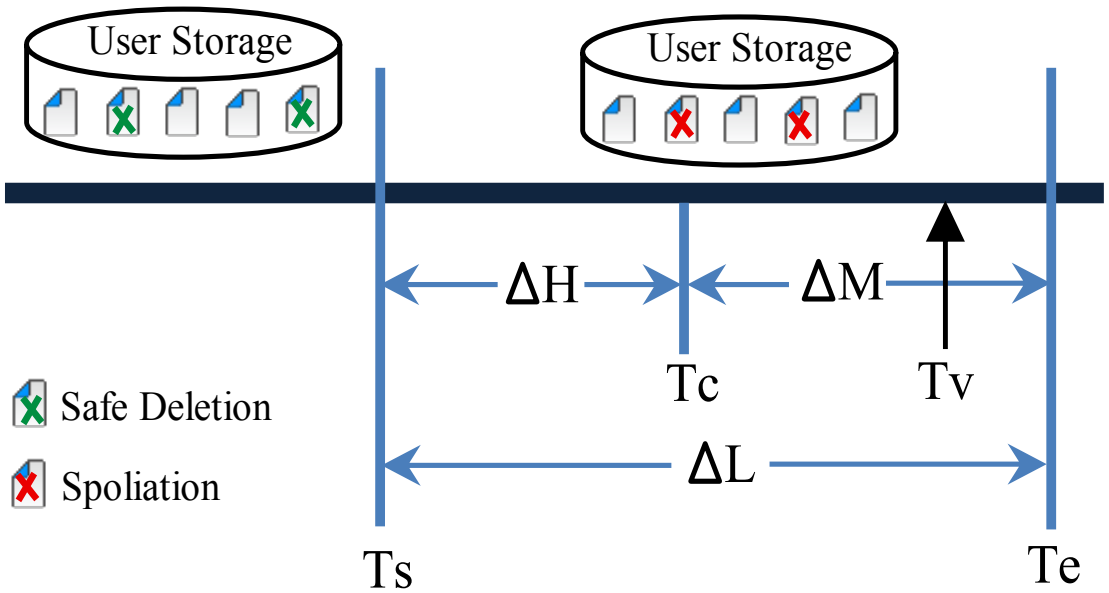
$\Delta L = T_e - T_s$

T_c: CSP turns malicious

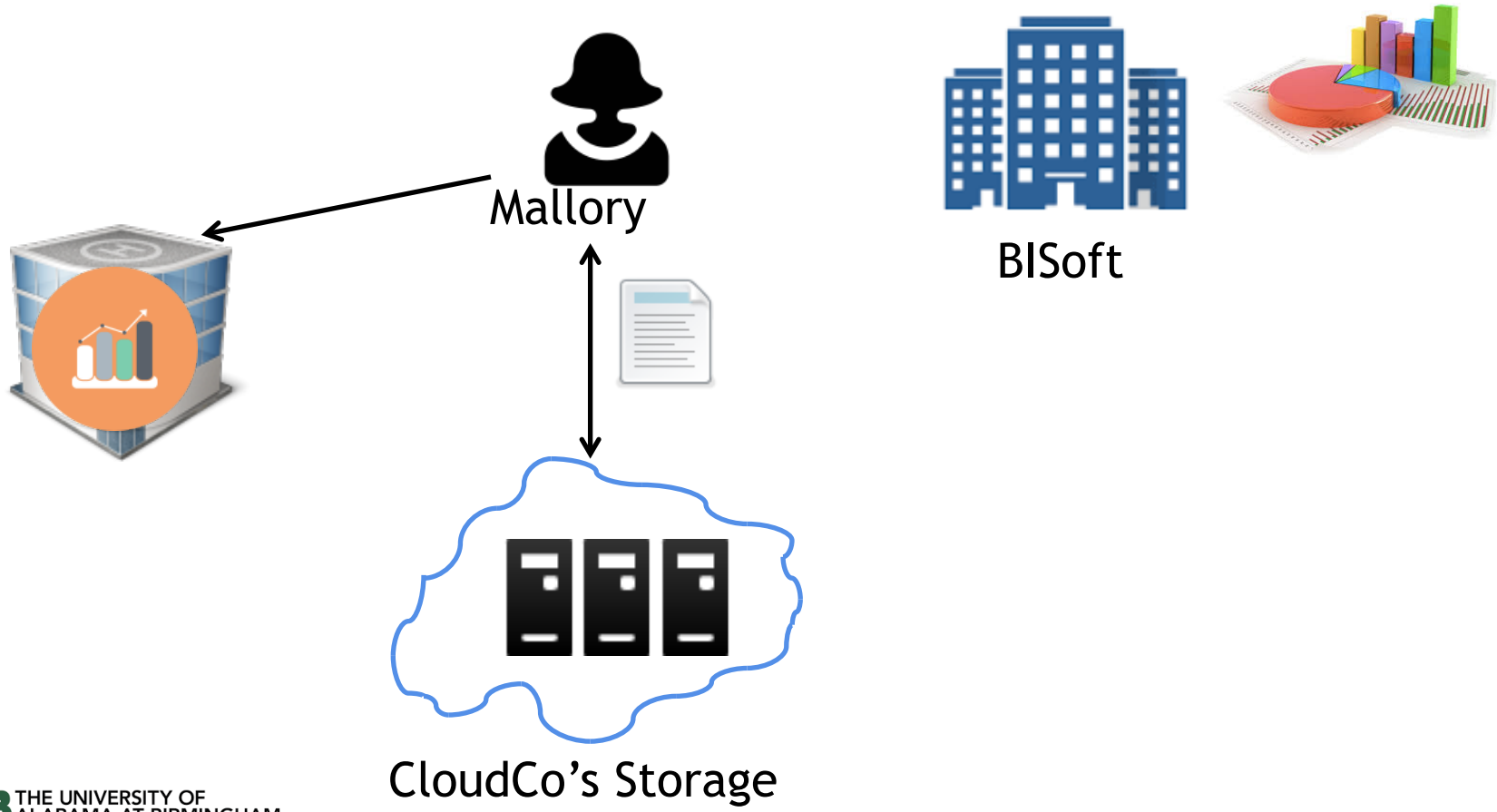
$\Delta H = T_c - T_s$, $H > 0$

$\Delta M = T_e - T_c$

T_v: Verification time



Motivation | Case Study



Motivation | Current Solutions

- Legal hold framework in clouds [Schmidt (2012)]
- Provable Data Possession schemes in clouds [Ateniese et al. (2007); Erway et al. (2009)],

-Schmidt, O., 2012. Managing a legal hold on cloud documents. US Patent App.13/543,254.
-Ateniese, G., Burns, R., Curtmola, R., Herring, J., Kissner, L., Peterson, Z., Song, D., 2007. Provable data possession at untrusted stores. In: 14th ACM conference on Computer and communications security. ACM, pp. 598–609.
-Erway, C., Kupcu, A., Papamanthou, C., Tamassia, R., 2009. Dynamic provable data possession. In: 16th ACM conference on Computer and communications security. ACM, pp. 213–222.

Motivation | Research Gap

- Schmidt (2012): Cloud providers are considered as trustworthy
- PDP: Metadata are generated by clients, who are considered as trustworthy
- No one considered the collusion between CSP, plaintiff and defendant.

Proposing LINCS

- **LI**itigation hold e**N**abled **C**loud **S**torage (*LINCS*)
- Defendant or a plaintiff can collude with a malicious CSP
- Secure verifiable proof of file creation and deletion.

LINCS | Threat Model

C P D

- Removes files on hold from the cloud storage
- Denies the ownership of files presented by plaintiff

C P D

- Bypass the proof of deletion preservation system
- Remove the proof of file
- Present an act of spoliation as a safe deletion operation
- deny hosting a file presented by plaintiff

LINCS | Threat Model

C P D

- Remove file without defendant's consent.
- Present a safe deletion operation as an act of spoliation
- Plant a back-dated fake file to the defendant's storage

C P D

- External attackers extract information from proofs of files or the proofs of file deletions

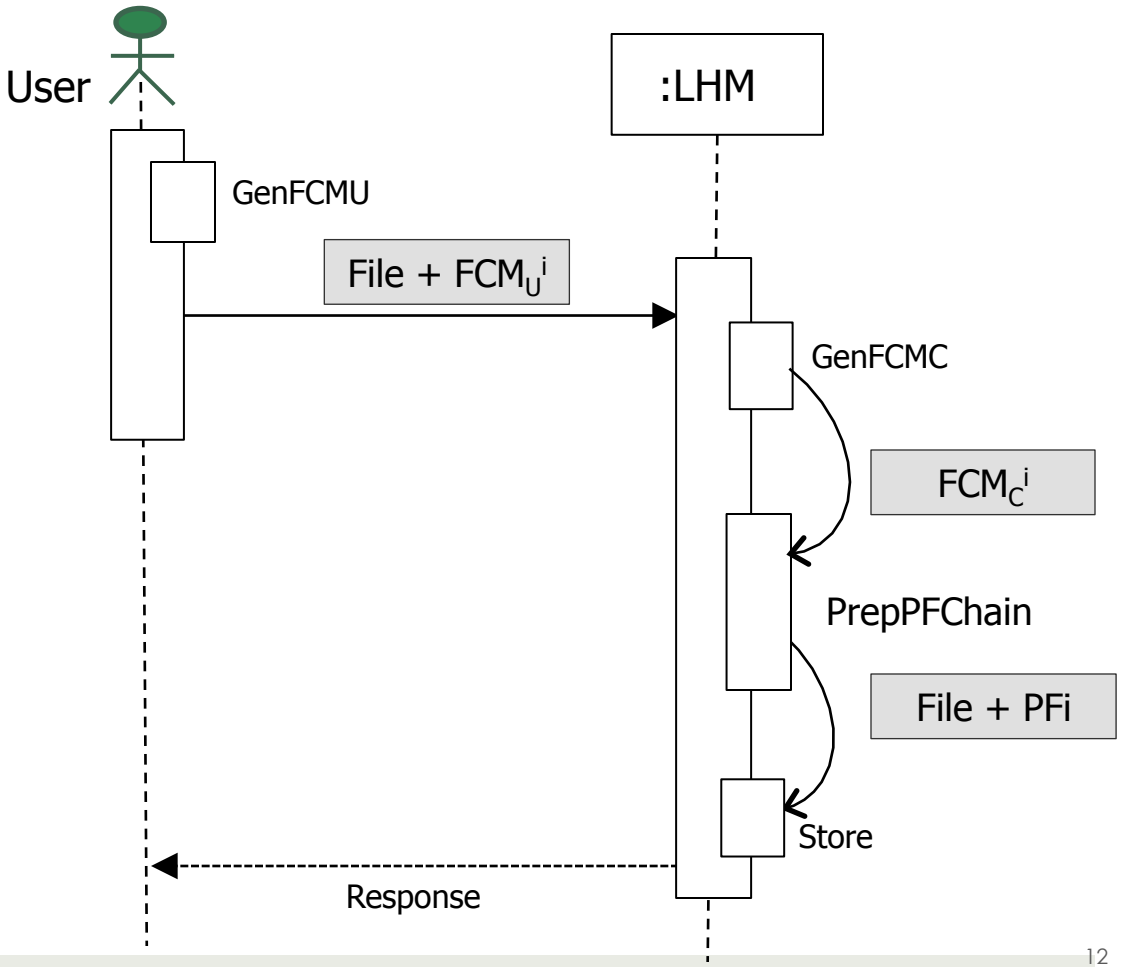
LINCS | File Upload Protocol

$FCM_U^i =< (H(F^i)|F^i_{ID} |CT_U),$
$Sig\ (H(F^i)|F^i_{ID} |CT_U)>$

$FCM_C^i =< (H(F^i)|F^i_{ID} |CT_C),$
$Sig\ (H(F^i)|F^i_{ID} |CT_C)>$

$PF^i =< Mac_{MKCi}\ (CS^i),(CS^i) >$
$CS^i = <FCM_U^i|FCM_C^i >$

$MK_C^i =< MKey(H(MK_C^{i-1})) >,$
$MK_C^0 =< MKey(H(S_C)) >$



LINCS | File Deletion Protocol

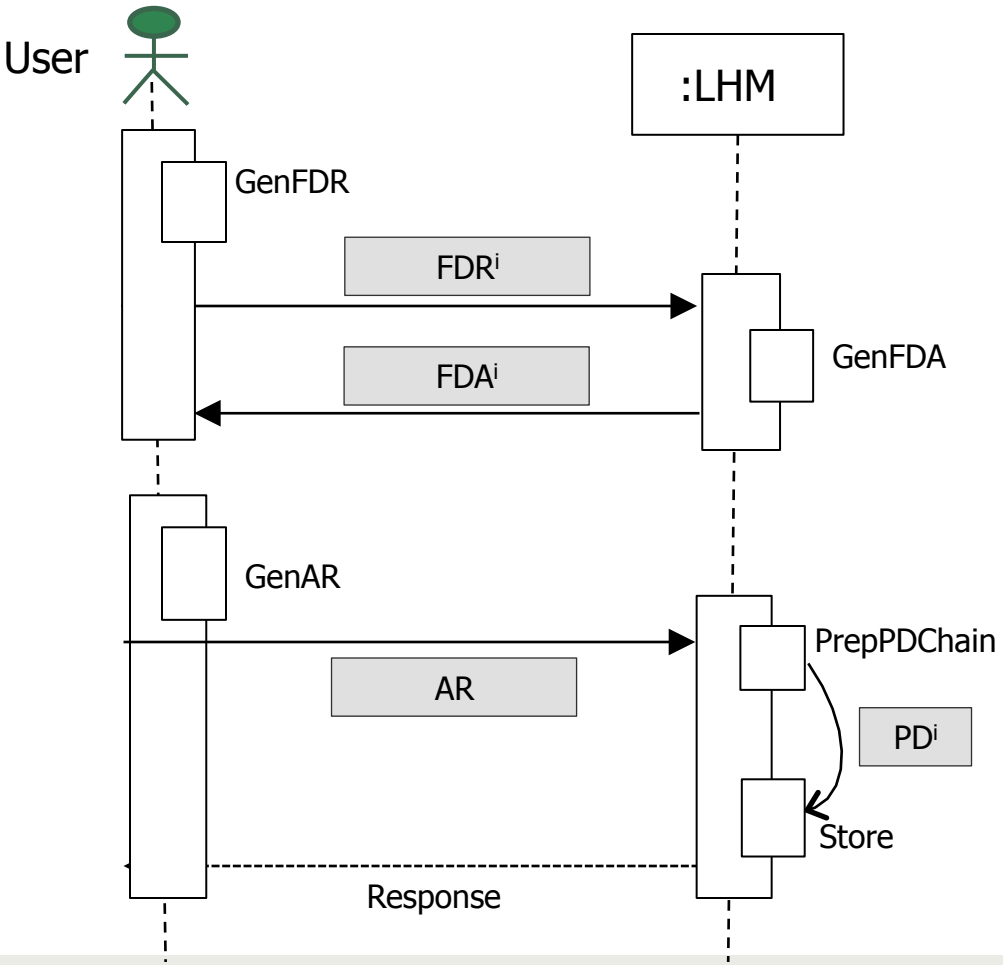
$FDR^i =< (H(F^i)|F^i_{ID}|DT_U),$
$Sig\ (H(F^i)|F^i_{ID}|DT_U)>$

$FDA^i =< (H(F^i)|F^i_{ID}|DT_C),$
$Sig\ (H(F^i)|F^i_{ID}|DT_C)>$

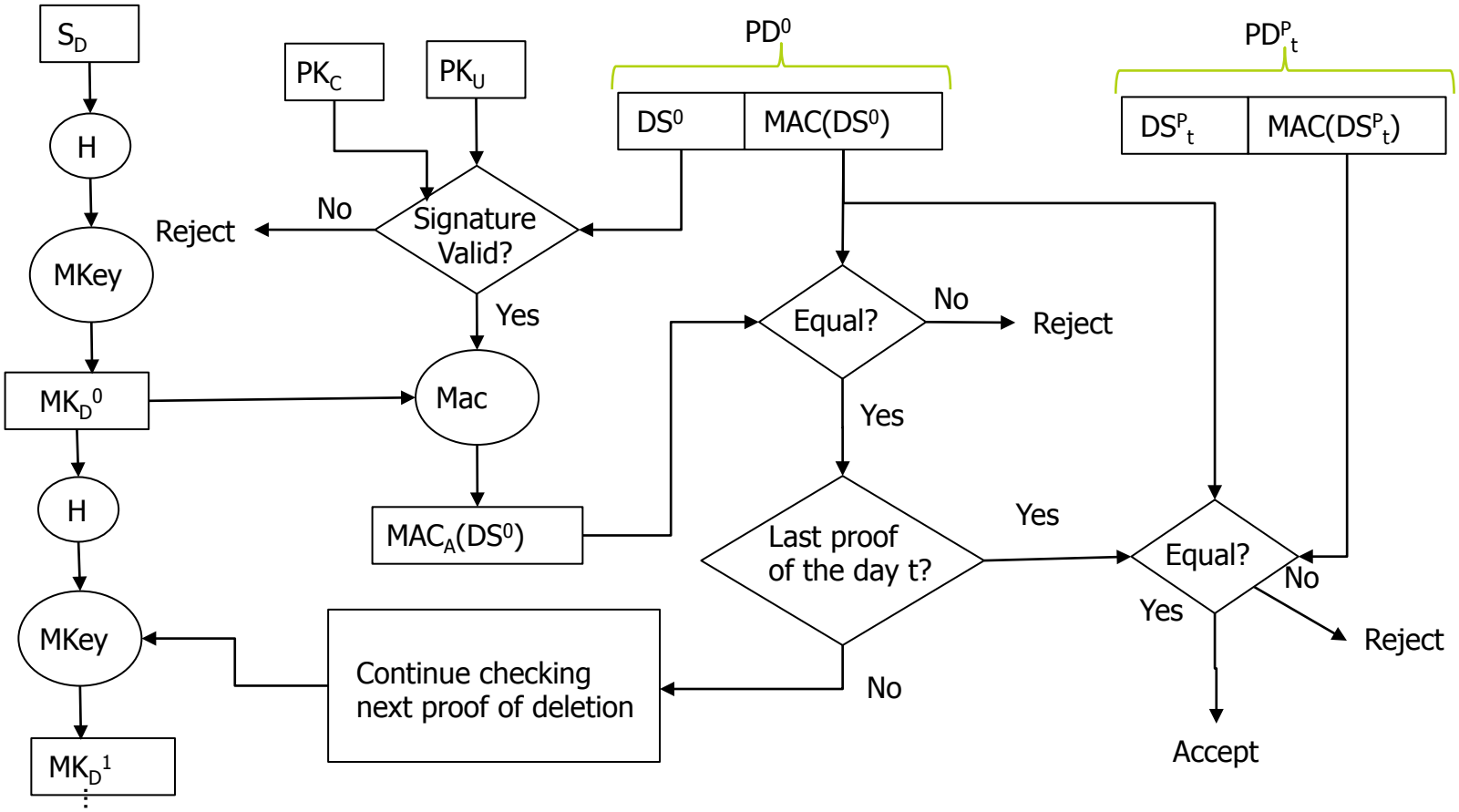
$AR =< (Response|F^i_{ID}|AT_U), Sig$
$(Response|F^i_{ID}|AT_U)>$

$PD^i =< Mac_{MKDi}(DS^i),(DS^i) >$
$DS^i = <FDR^i|FDA^i|\ AR >$

$MK_D^i =< MKey(H(MK_D^{i-1})) >,$
$MK_D^0 =< MKey(H(S_D)) >$



LINCS | Verification



LINCS | Security Propositions

Proposition 1: Defendant cannot deny the possession of a file F^i

- PF^i is attached with the F^i a metadata.
- PF^i includes $FCM_U{}^i$, which contains the signature of the defendant

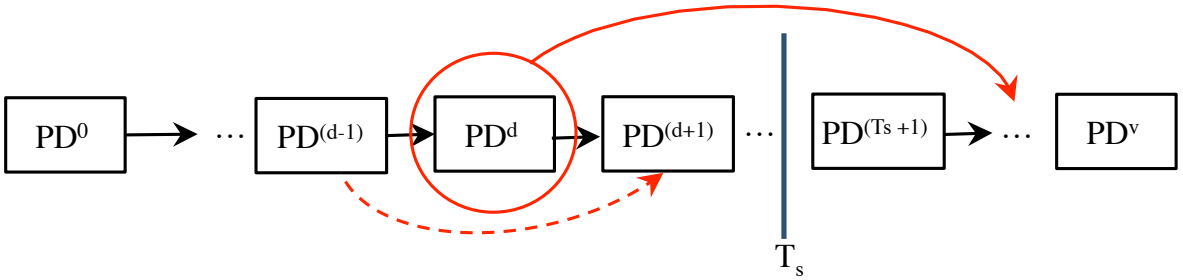
LINCS | Security Propositions

Proposition 2: *Defendant cannot deny the proof of deletion* PD^i *for the* F^i *file*

- PD^i for the F^i contains file deletion request FDR^i and acknowledgement receipt AR
- Defendant signed these two components

LINCS | Security Propositions

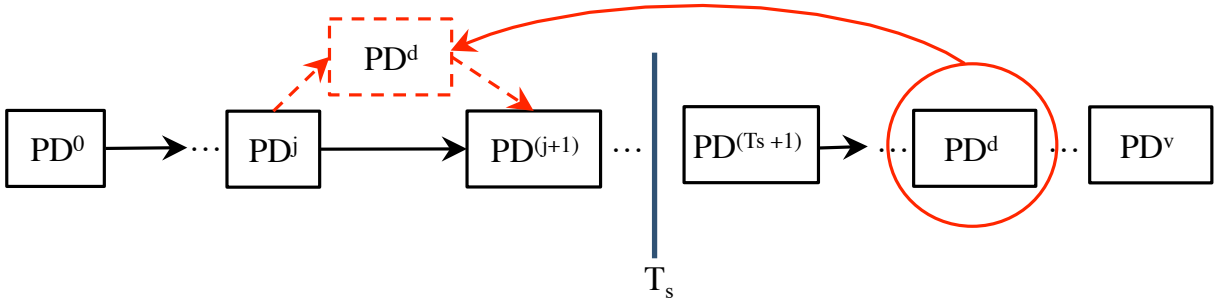
Proposition 3: If F^d *is removed before* Ts, PD^d *cannot be placed after* Ts



- PD^{d+1} will be appeared after PD^{d-1} in the altered proof of deletion chain.
- At i=d, the auditor creates $MAC_A(DS^{d+1})$ from the MAC key MK_D^d , but the actual $MAC(DS^{d+1})$ was created using MK_D^{d+1}

LINCS | Security Propositions

Proposition 4: If F^d is removed after Ts , PD^d cannot be placed before Ts



- PD^d will be appeared after PD^j in the altered proof of deletion chain.
- $MAC_A(DS^d)$!= $MAC(DS^d)$, since the $MAC(DS^d)$ was not calculated using the key MK_D^{j+1}

LINCS | Security Propositions

Proposition 5: Auditor can detect the act of spoliation if a defendant removes a file F^d during ΔL and *the plaintiff presents the file* F^d *to the court*

- There must be a proof of deletion PD^d
- PF^d can prove the existence of the file F^d in the defendant's cloud storage

LINCS | Security Propositions

Proposition 6: F^d is removed without the defendant's consent, the plaintiff cannot prove this deletion as an act of spoliation.

- The plaintiff needs to present the proof of deletion PD^d
- PD^d should contain the defendant's signature with the FDR^d and the AR

LINCS | Security Propositions

Proposition 7: CSP cannot add a fake file F^f to the defendant's storage without being detected by the auditor.

- The PF^f includes FCM_U^f , which is signed by the defendant.
- Presenting the F^f file as a backdated file requires modification in the chain of PF

LINCS | Security Propositions

Proposition 8: An adversary cannot identify the content of the file Fi from the PF^i or PD^i

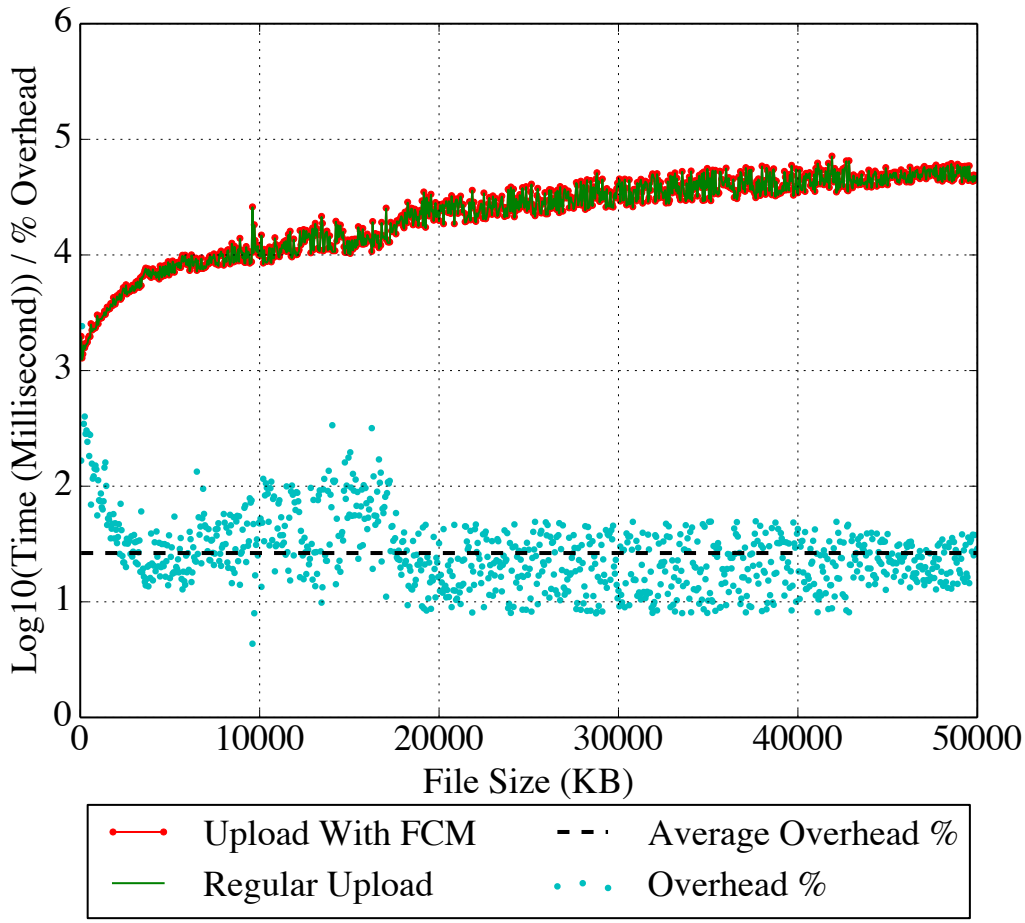
- PF^i and the proof of deletion PD^i are created from the hash of the F^i
- One- way, collusion resistant hash function prevents reverse engineering the proofs

LINCS | Results

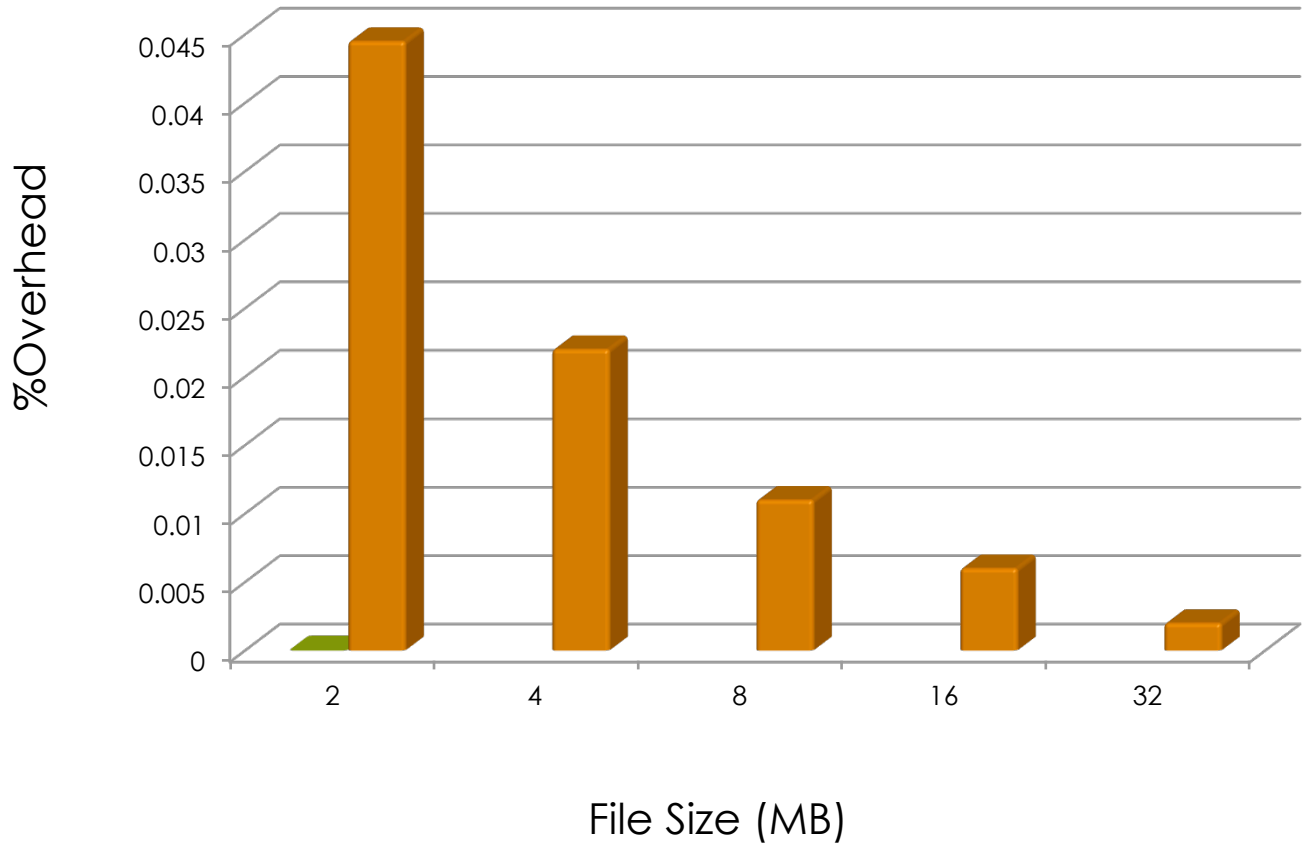
System Configuration

- Ftp server in an AmazonEC2 medium (m1.medium) instance running Ubuntu 12.04.4 LTS
- (LHM) module was running inside the EC2 instance
- RSA (2048 bit) for encryption, SHA-256
- Oracle JDK (version1.7.051) to implement the modules of *LINCS*

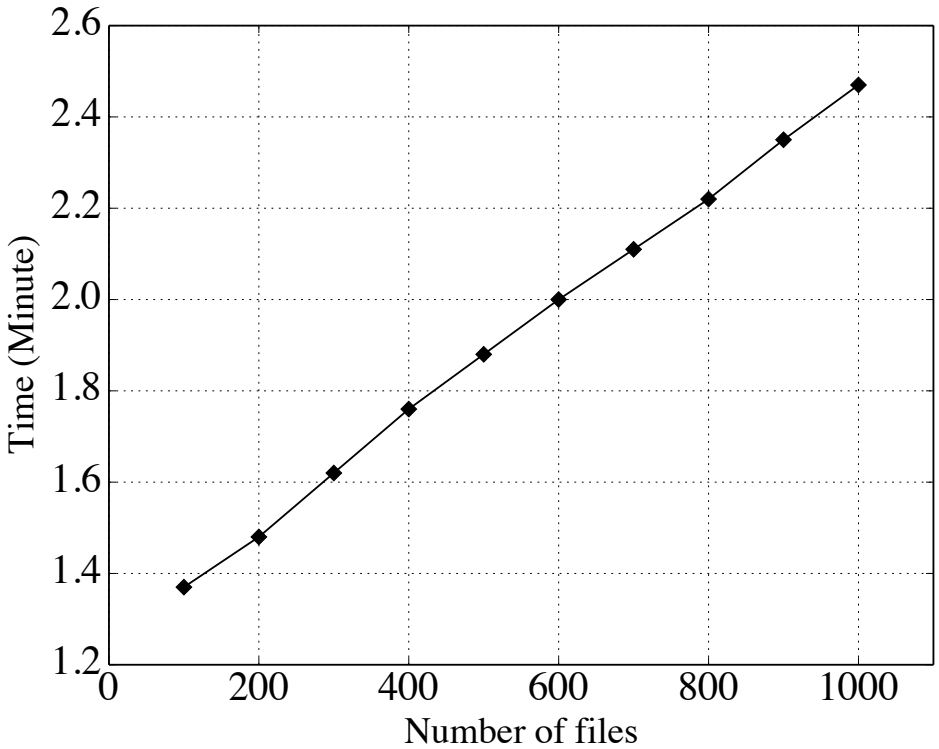
LINCS | Client Overhead

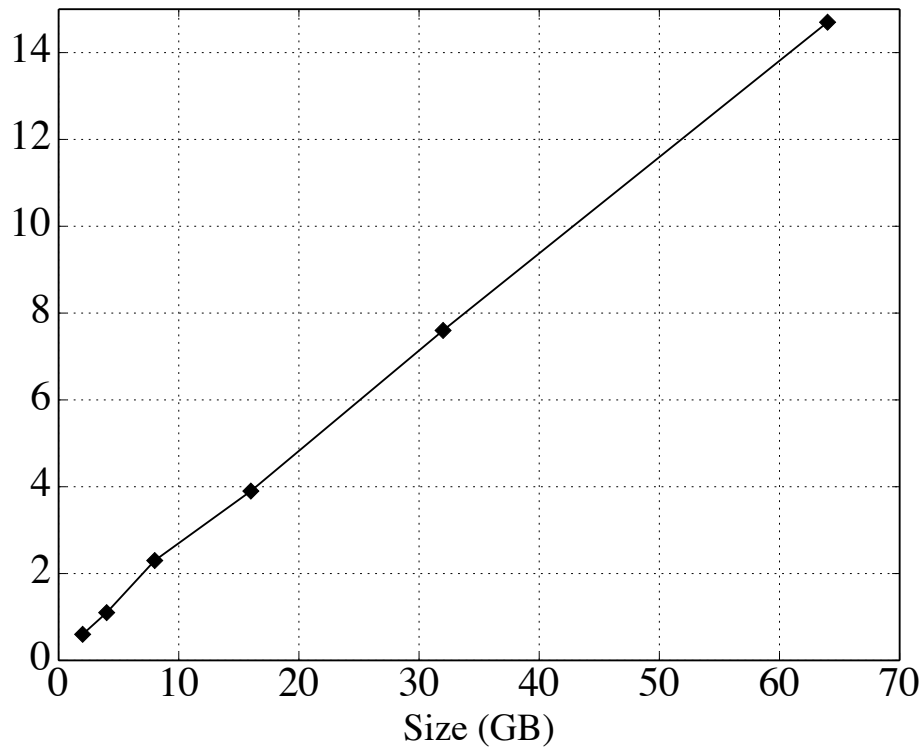


LINCS | Storage Overhead

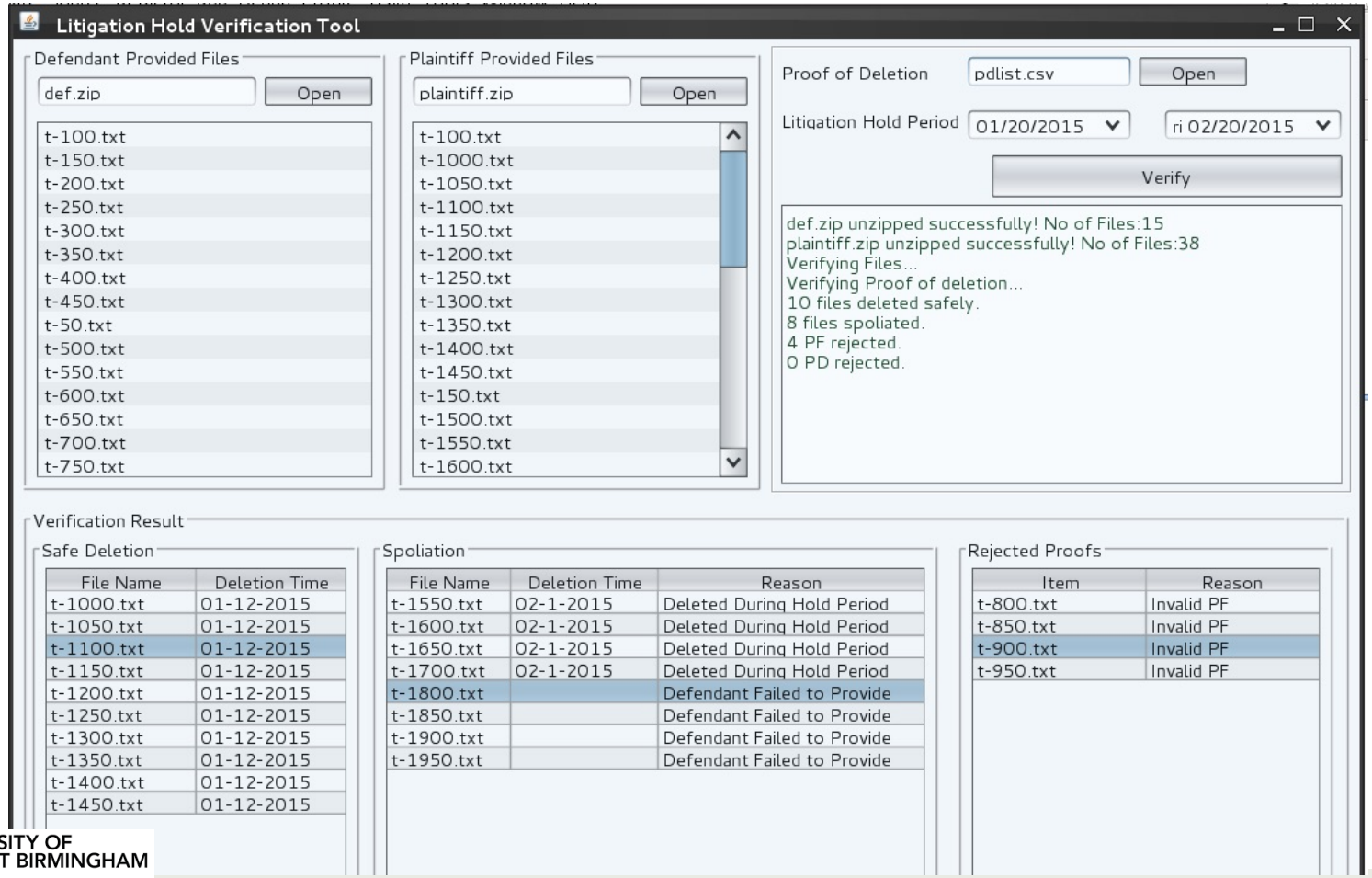


LINCS | Verification Performance





LINCS | Verification Tool



Conclusion & Future Work

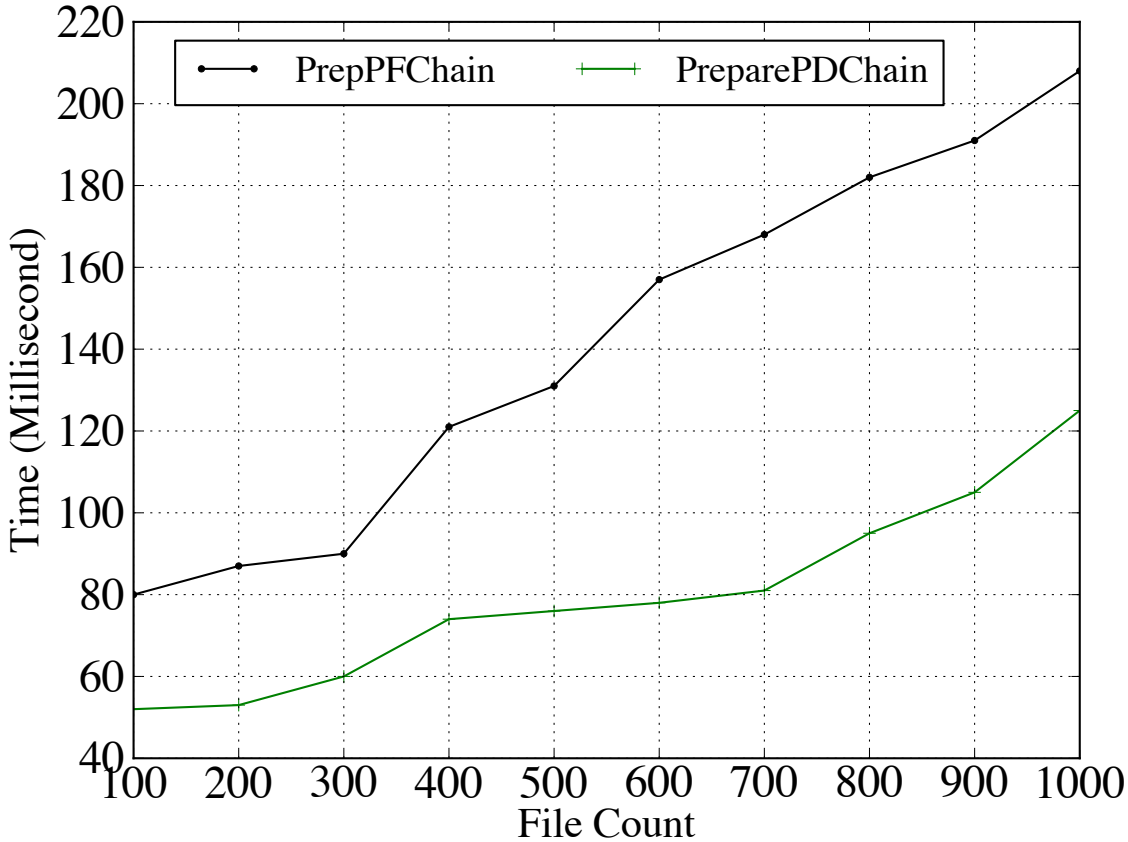
- Defined a model of trustworthy litigation holds in clouds
- Proposed *LINCS* that ensures trustworthy management of litigation holds in a cloud storage.
- Future Plan:
  - Include dynamic behavior of the cloud storage,
  - New files creation after Ts,
  - Security of the special types of file, such as MBOX or EML .

Thank You

Shams Zawoad

- zawoad@cis.uab.edu

LINCS | Proof Creation Performance



LINCS | Security | Lemma

Lemma 1: PF^i is the proof provided by the user and the CSP about the existence of the F^i file

Lemma 2: PD^i is the proof provided by the user and the CSP about the deletion of the F^i file.

Lemma 3: The secret keys and the initial secrets S_D and S_C cannot be accessed by an adversary.

Lemma 4: CSP cannot alter the published proofs or deny the existence of the published proofs