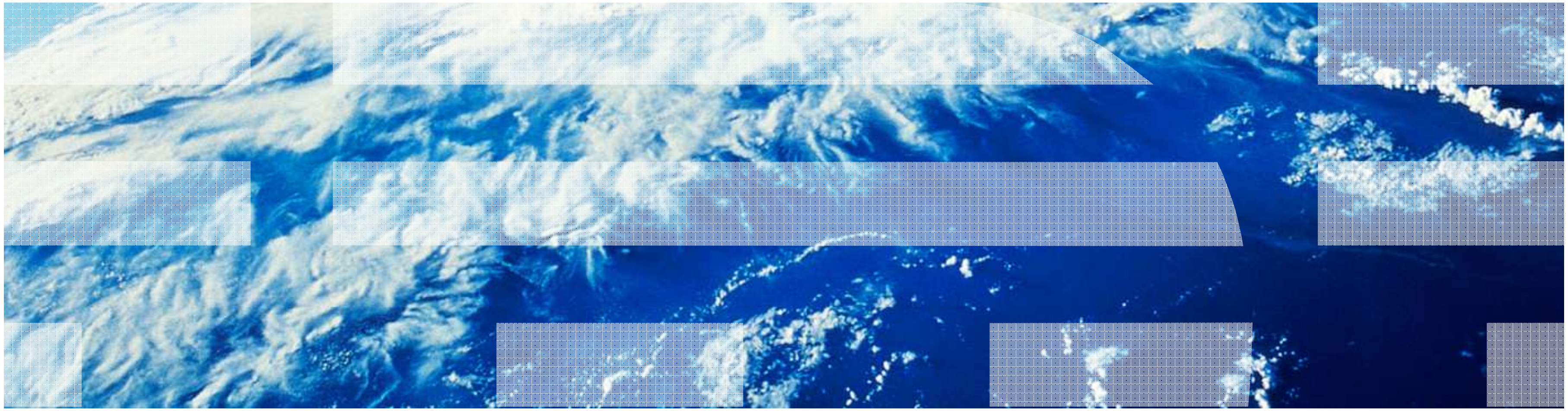
Practical Yet Universally Composable Two-Server Password-Authenticated Secret Sharing



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Password breaches summer 2012

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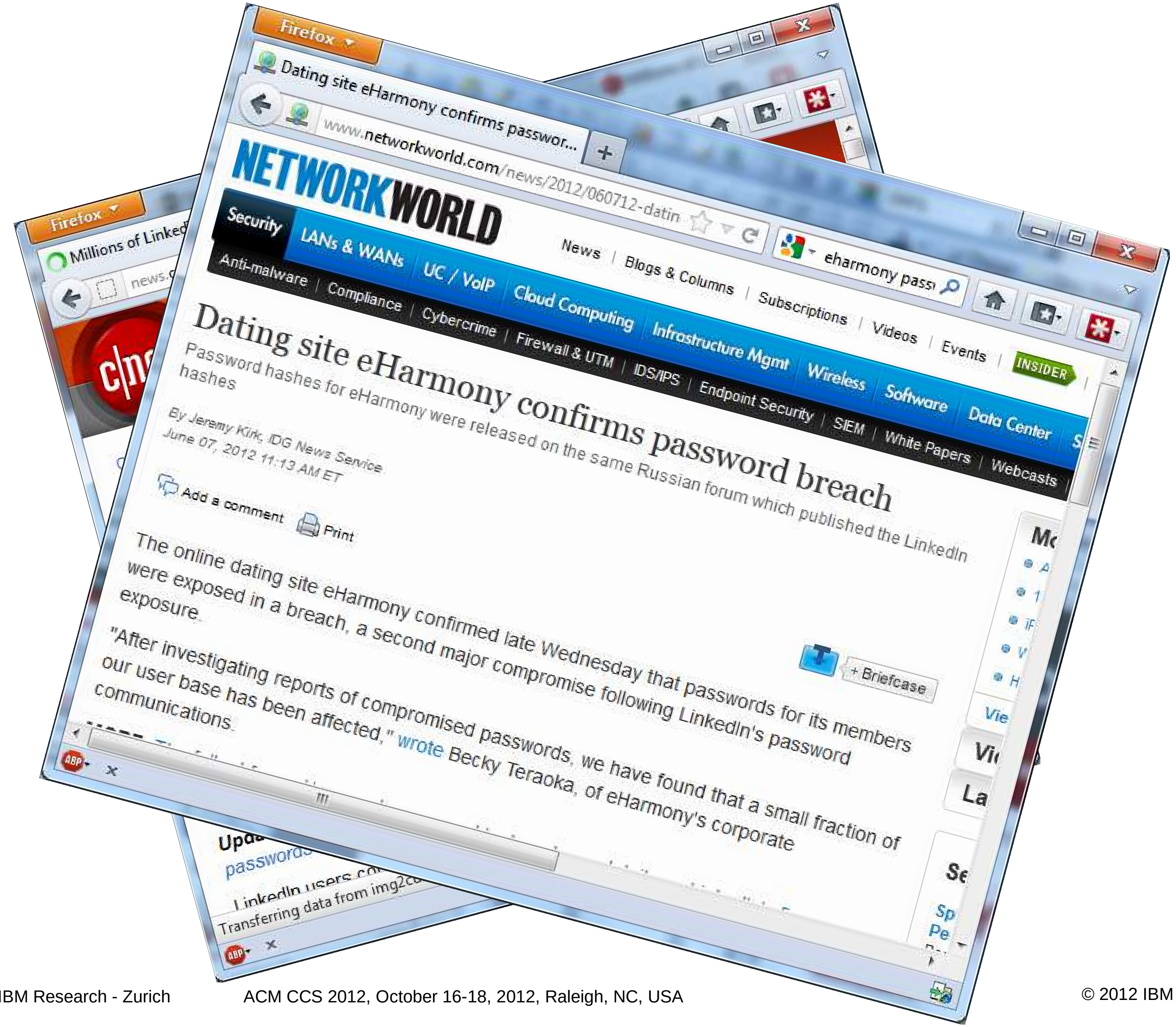

Password breaches summer 2012

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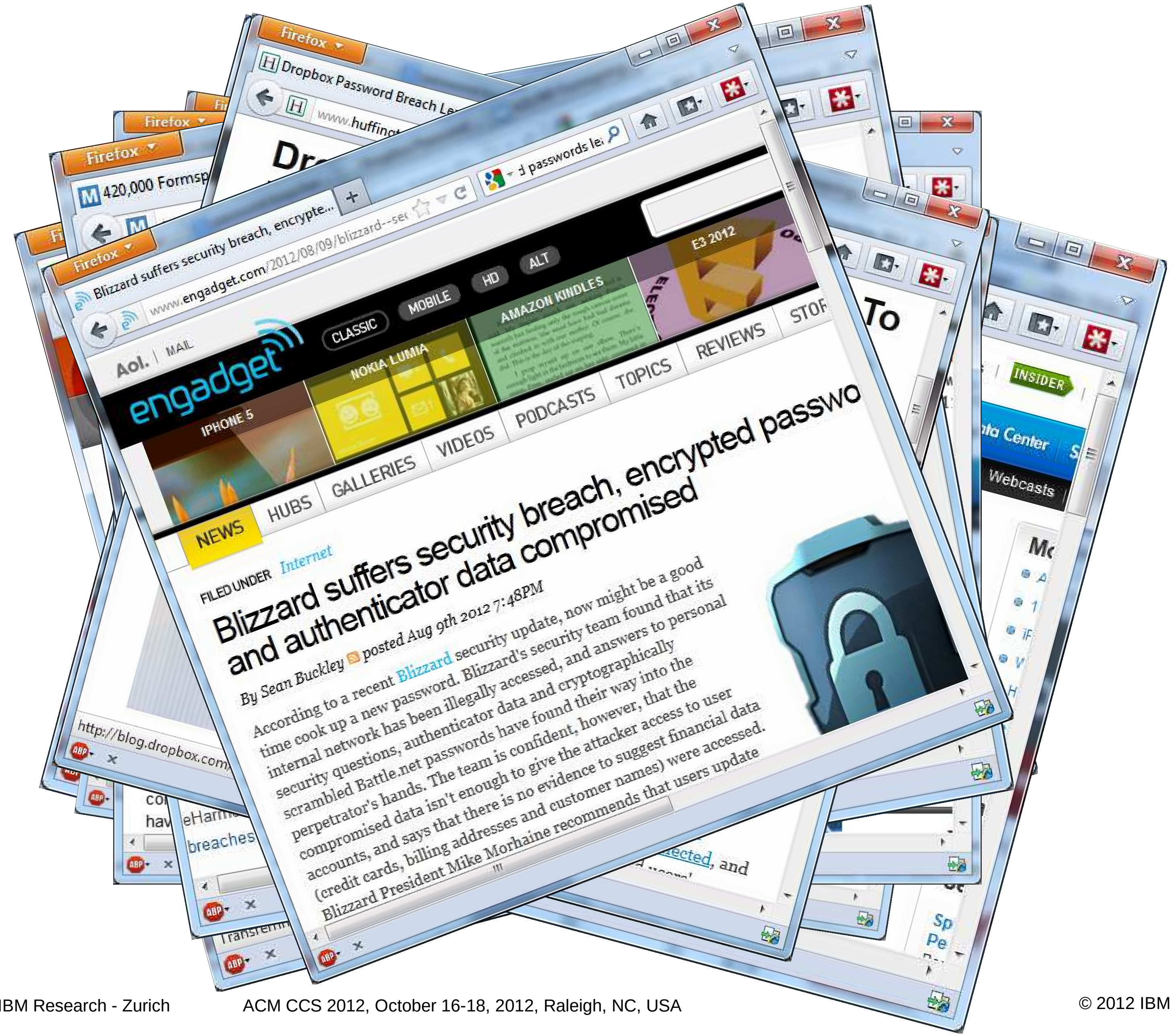
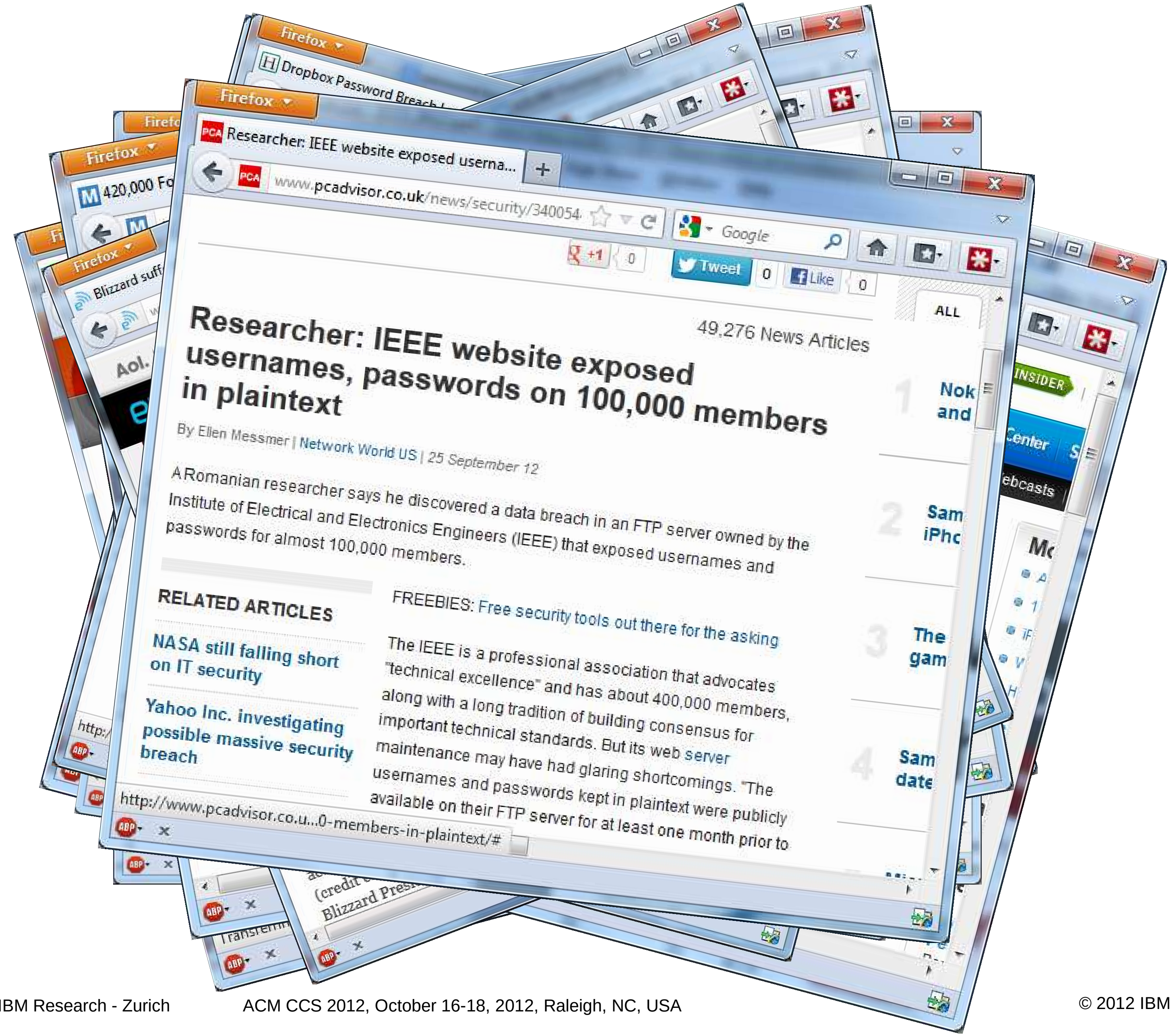


Password breaches summer 2012



Remedies

- Use strong, hard-to-guess passwords
- Use different passwords for different sites
- Change passwords on regular basis
- Don’t write passwords down

… yeah, right.

The root of the problem (1)

- Passwords inherently insecure?
  No! We're just using them incorrectly

- **Problem 1:** Passwords useless against offline attacks
  - 16-character passwords ≈ 30 bits entropy [NIST] ≥ 1bn possibilities
  - $150 GPUs test several bn per second
  - 60% of LinkedIn passwords cracked within 24h
  - Online cracking services:
    $17 for 3bn words, $136 for 25tn, ready in 2h

- Passwords quite effective against online attacks, iff "throttling":
  block account/IP, CAPTCHAs, time delays after failed attempts

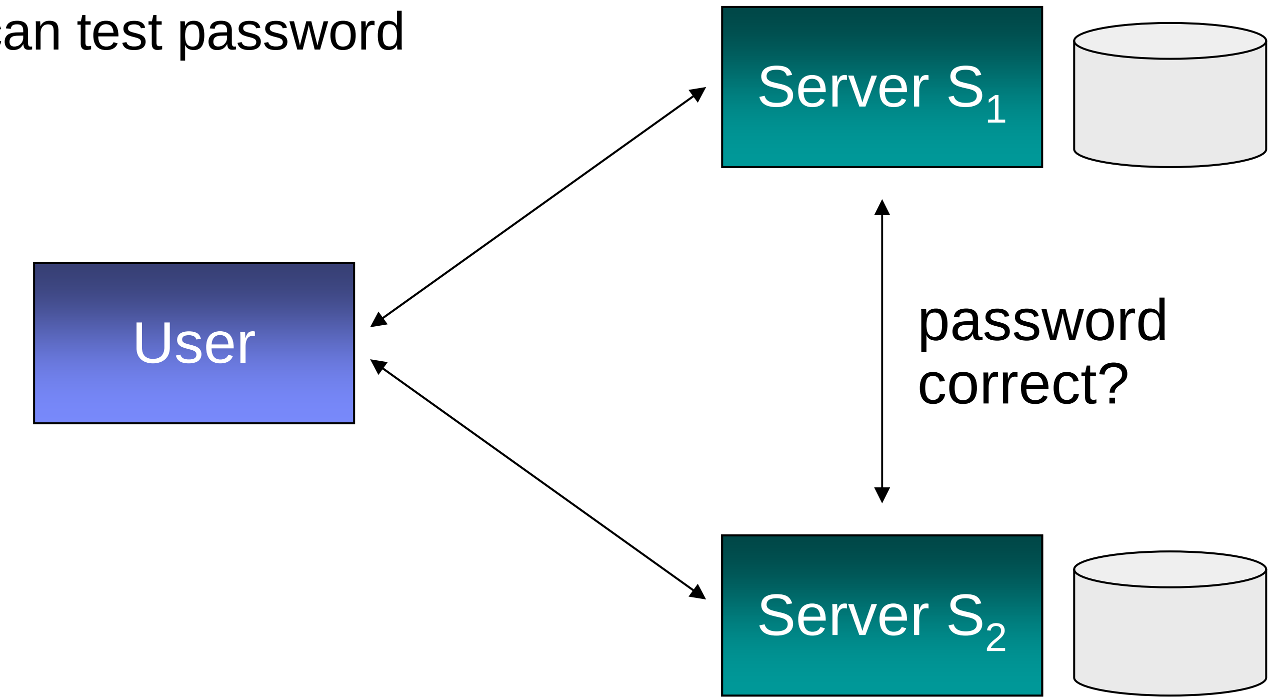
The root of the problem (2)

- **Problem 2:** Single-server solutions inherently vulnerable to offline attacks:

  server/hacker can always guess & test

- **Solution:** multi-server password verification protocols

  no server alone can test password



Overview

- Design goals & related work
- Universally composable security for 2PASS
- Protocol idea
- Conclusion

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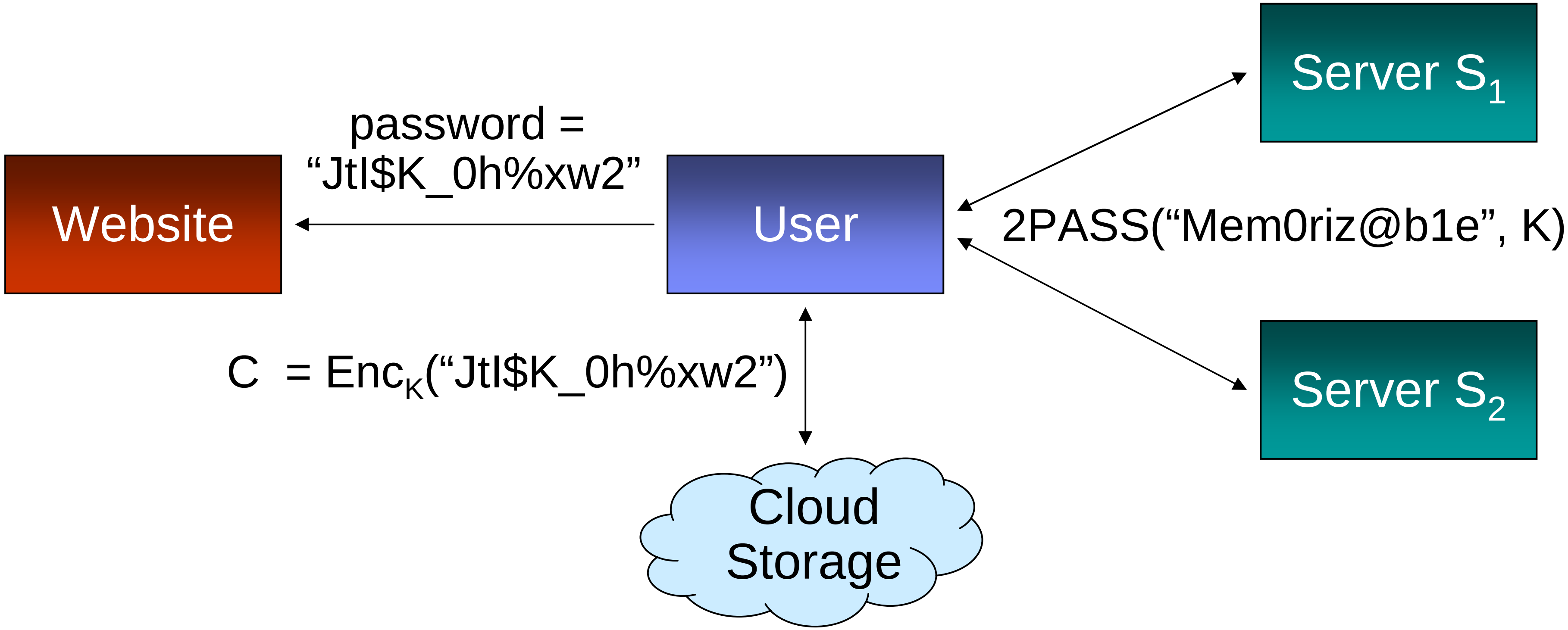
Design goals

Two-server password-authenticated secret sharing (2PASS)

- User remembers username, password, server names
- Store & reconstruct strong secret K
  (and thereby any encrypted data)
- Single corrupt server cannot
  - perform offline attack on password (attempts)
  - learn stored secret K
  - convince honest server that wrong password is correct
- Assume PKI
  (e.g., hardcoded in client software)

Killer application: distributed password store



- One person, one password
- No (hacker of) single 2PASS server can steal website passwords
- Websites keep ordinary username/password infrastructure

Related work

Multi-server password-authenticated secret sharing (PASS)

- Bagherzandi et al. (2011):
  t-out-of-n servers, property-based security proofs

Multi-server password-authenticated key exchange (PAKE)

- Ford-Kaliski (2000), Jablon (2001), Brainard et al. (2003):
  no security proofs
- MacKenzie et al. (2002), Di Raimondo-Gennaro (2003), Szydlo-Kaliski (2005), Katz et al. (2005)
  property-based proofs

Long line of work on single-server PAKE

Our contribution: first universally composable (UC) 2PASS

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The case for UC in password-based protocols

Property-based definitions

- Passwords chosen according to known, independent distributions
  (reality: people reuse, share, leak info about passwords)
- Adversary sees authentications with **correct** password only
  (reality: typos!)
- Problematic w.r.t. composition due to non-negligible attack probability

UC definitions

- Environment chooses passwords & password attempts
  → no assumptions on distributions, typos covered
- Composes nicely with itself & other protocols

Overall: UC more natural & practically relevant for password-based protocols

2PASS ideal functionality

- At most one corrupt server
  - –doesn't learn anything about
    - password p
    - password attempt q
    - key K
  - –learns whether p=q only if all honest servers cooperate (throttling)
  - –cannot set honest user up with wrong K'
  - –cannot make honest server accept if p≠q
- Further complications to the model
  - –Avoid implying Byzantine agreement or atomic broadcast
  - –Multiple concurrent setup/retrieve queries
  - –Query hijacking

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Protocol: high-level idea

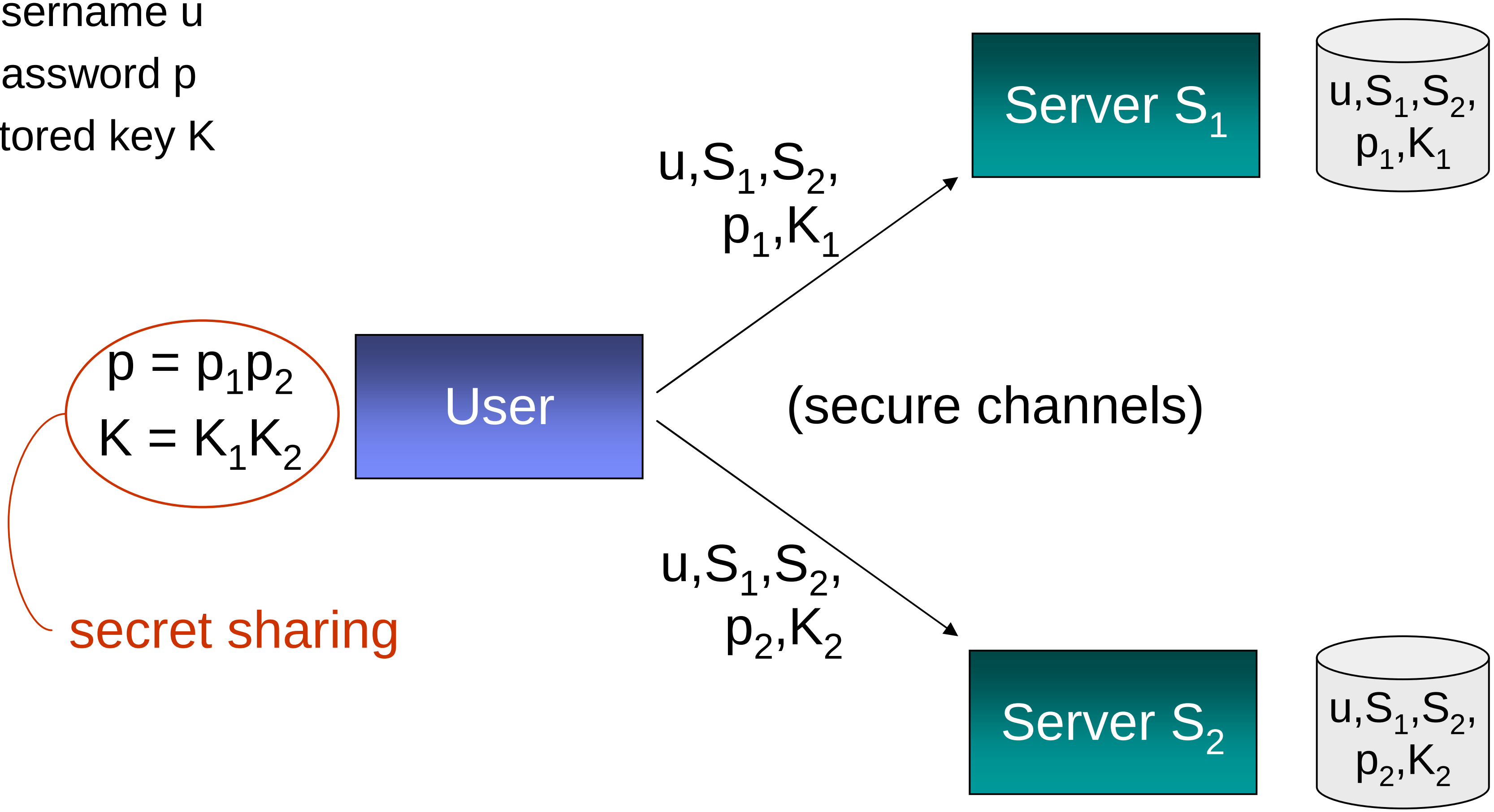
Setup

Brainard et al. (2003)

username u

password p

stored key K



Protocol: high-level idea

Retrieve

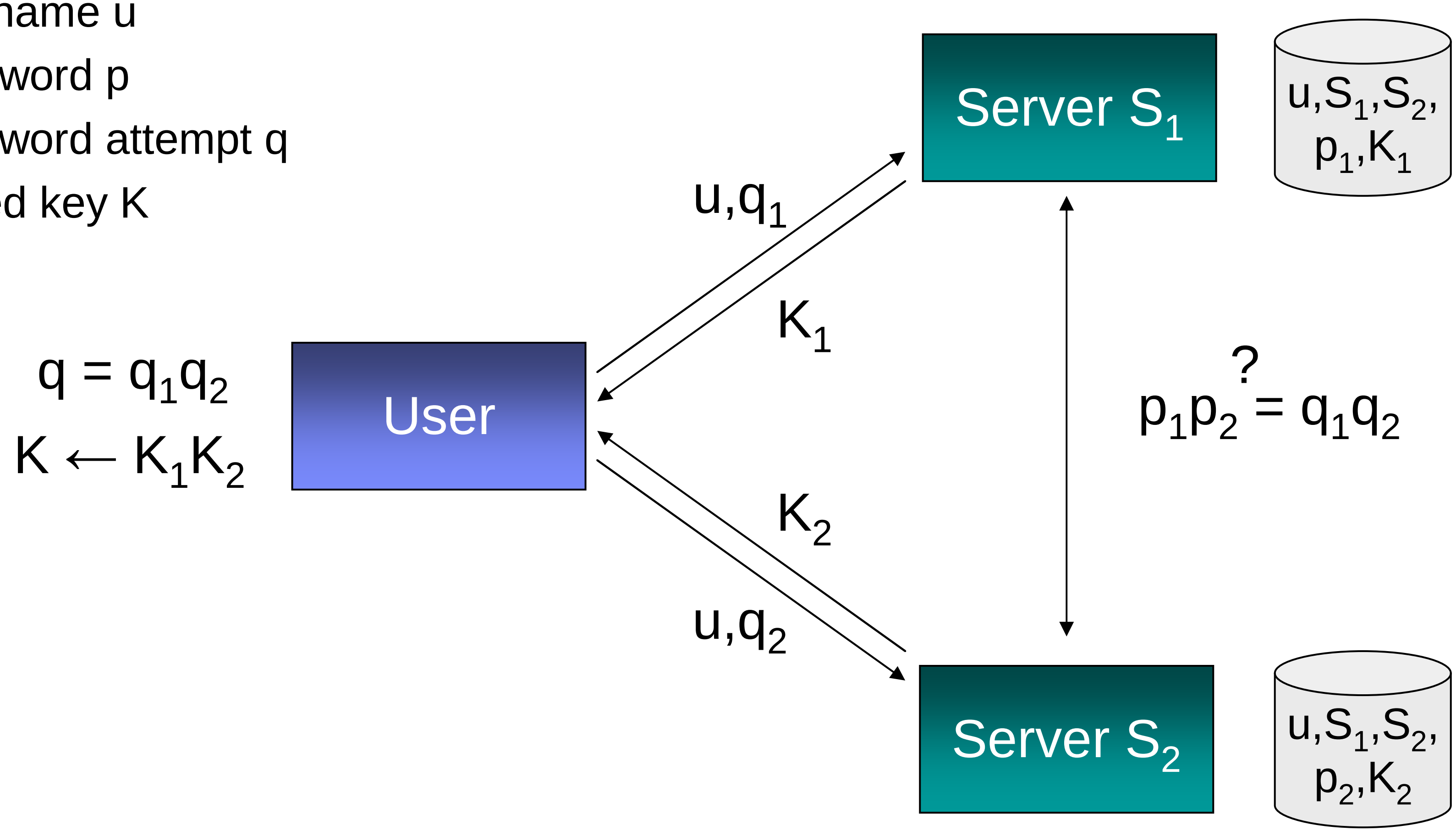
Brainard et al. (2003)

username u

password p

password attempt q

stored key K



Setup

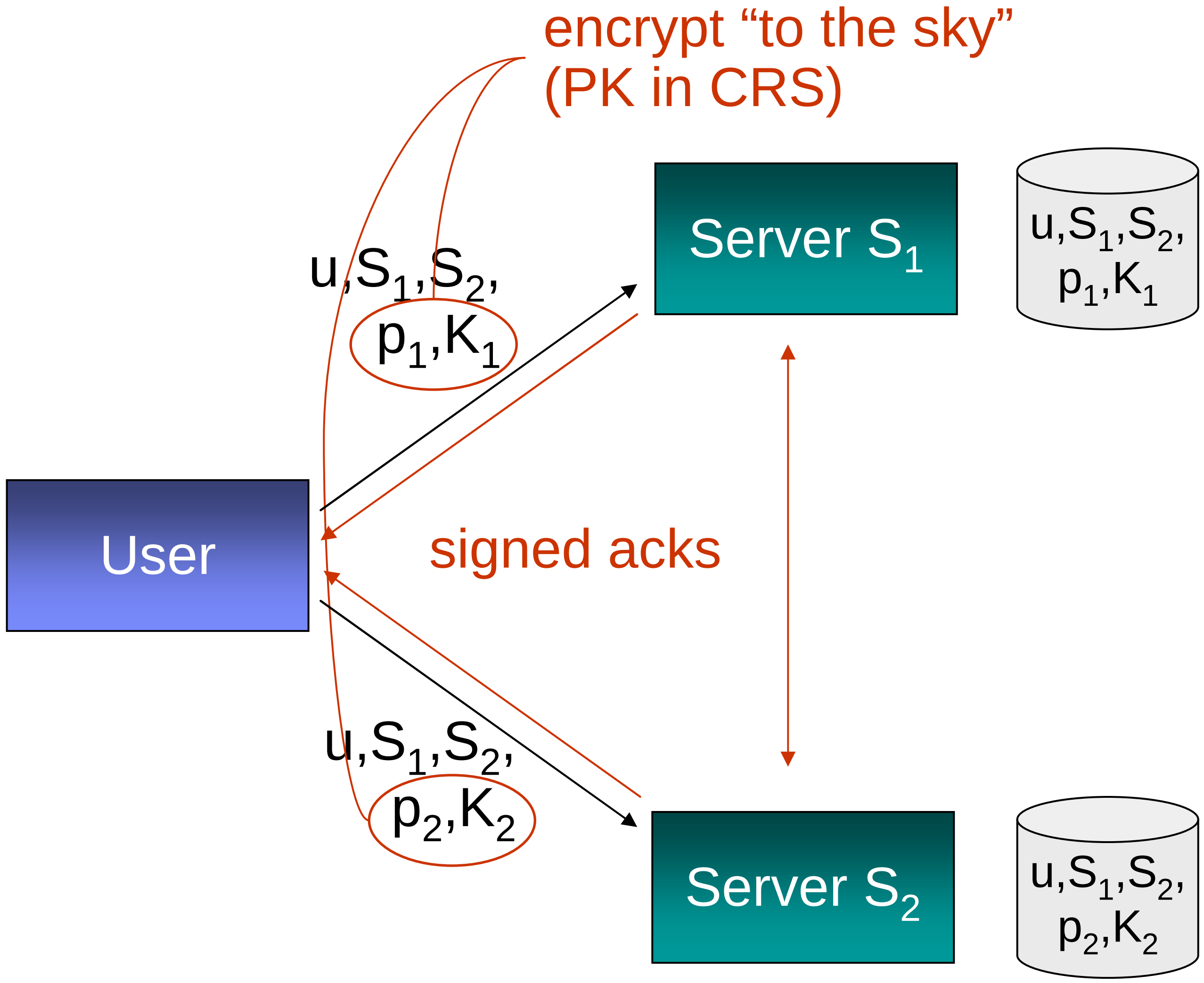
username u

password p

stored key K

$p = p_1 p_2$

$K = K_1 K_2$



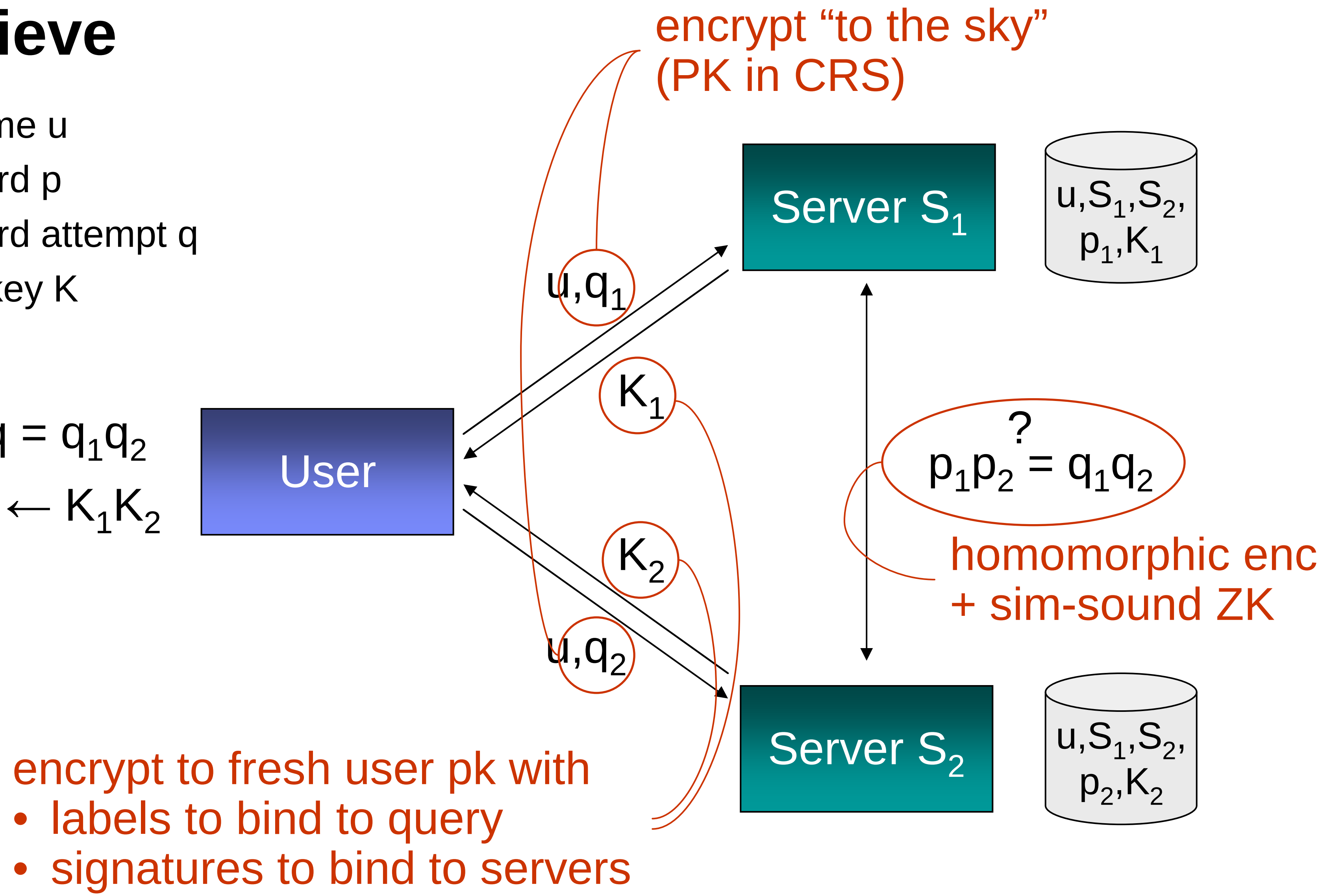
Protocol: UC strengthening

Retrieve

username u
password p
password attempt q
stored key K

$q = q_1 q_2$

$K \leftarrow K_1 K_2$



Efficiency

- Avoid heavy UC machinery by careful design
  - F_{CERT} and F_{CRS} as only UC subcomponents
  - CPA encryption to sky by revealing randomness
  - Efficient ZKPs in random-oracle model
- Most heavy lifting done by servers
- No additional secure channels needed (e.g., SSL)

	Setup	Retrieve
User comp	18 exp	19 exp
Server comp	10 exp	30 exp
User/Server comm	17 el	16 el
Server/Server comm	1 el	6 el, 9 exp, 3 hash

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Conclusion

- One person, one password
- Single-server solutions doomed, multi-server way to go
- UC security most natural model – beyond composability
- Efficiency through careful crypto design
- Many open problems – stay tuned ☺
  - t-out-of-n PASS
  - Adaptive corruptions
  - Password-only (i.e., no public keys)
  - …