Encrypted Access Logging for Online Accounts: Device Attributions without Device Tracking

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*Equal contribution by both authors.

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Accounts

Importance of Account Security Interfaces (ASIs)

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Account compromise is a frequent problem for survivors

- Abusers can often bypass authentication
- May not be safe to remove abuser
- Survivors often need to know whether access has occurred

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CETA
CLINIC TO END TECH ABUSE

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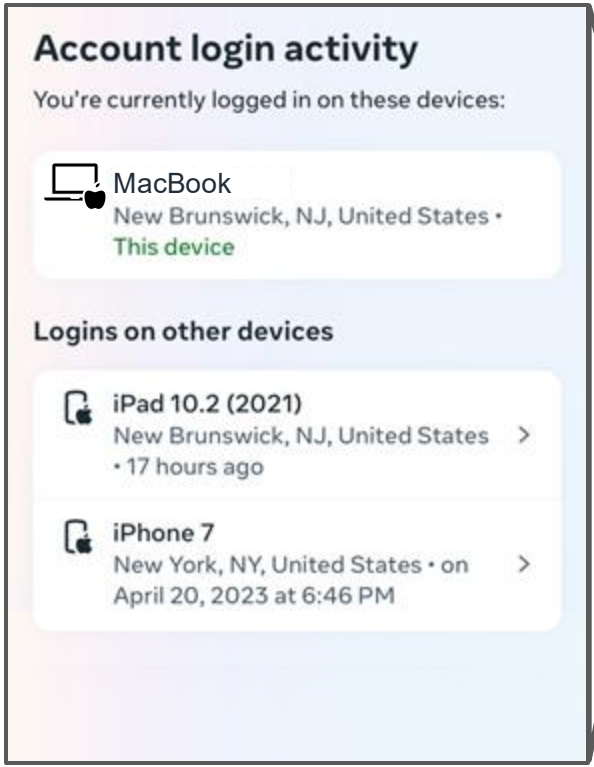

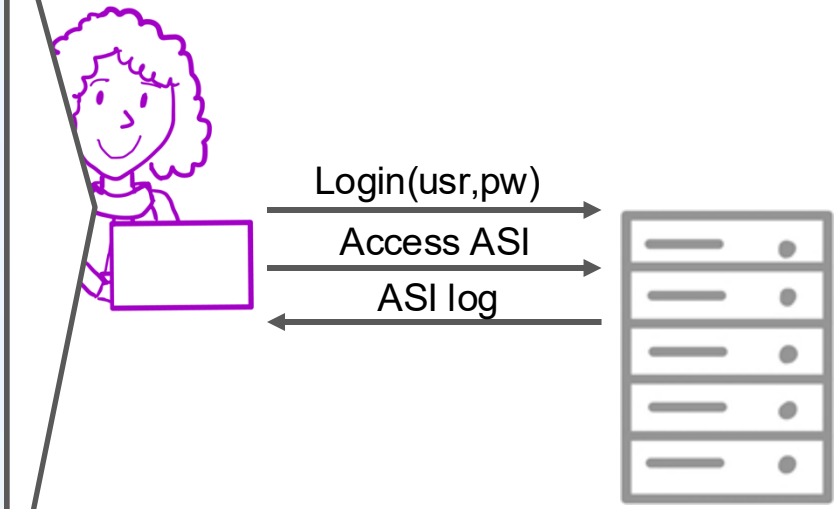

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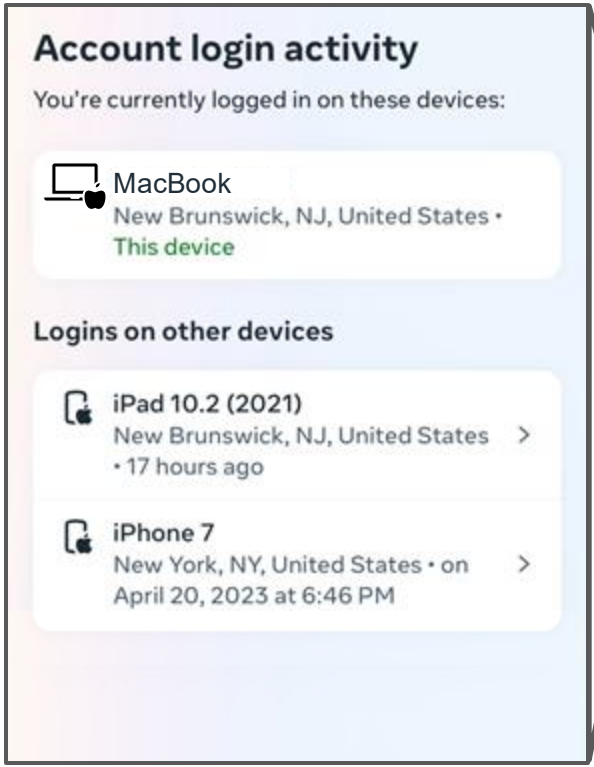

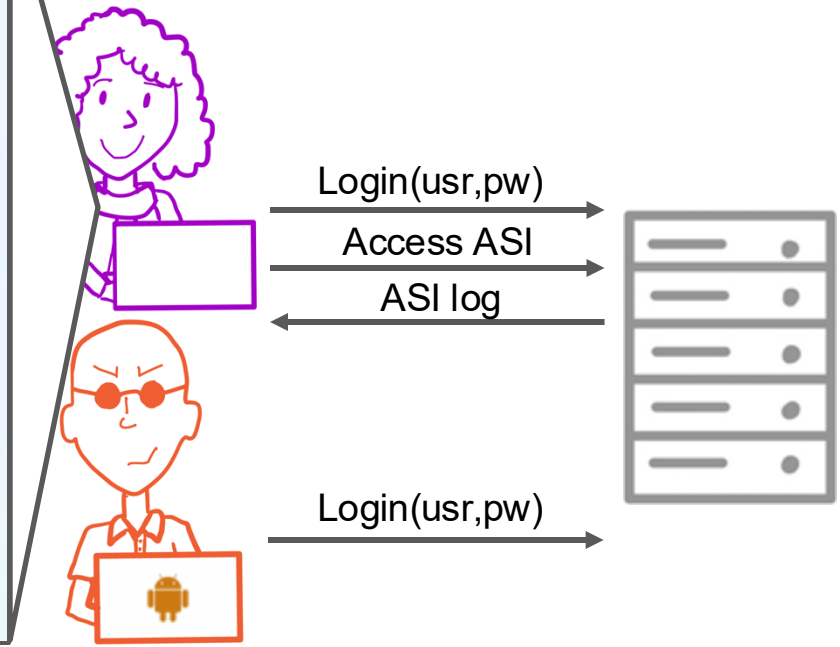

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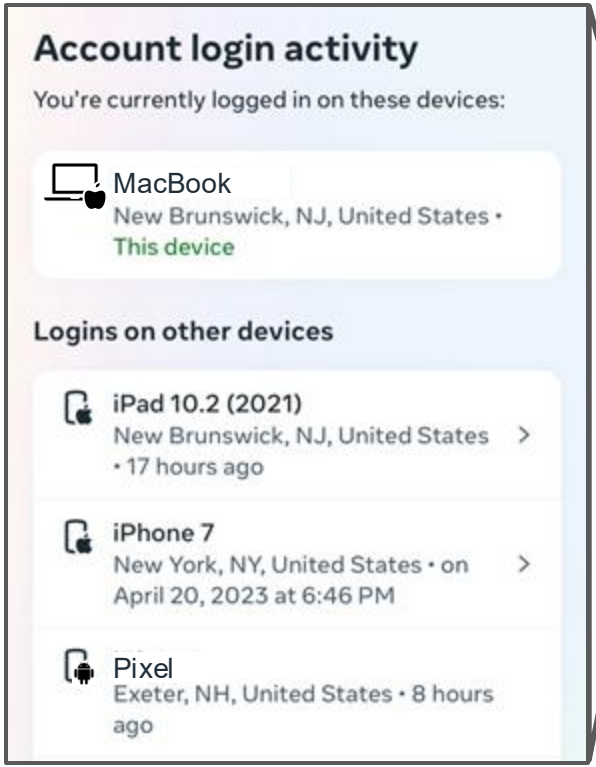

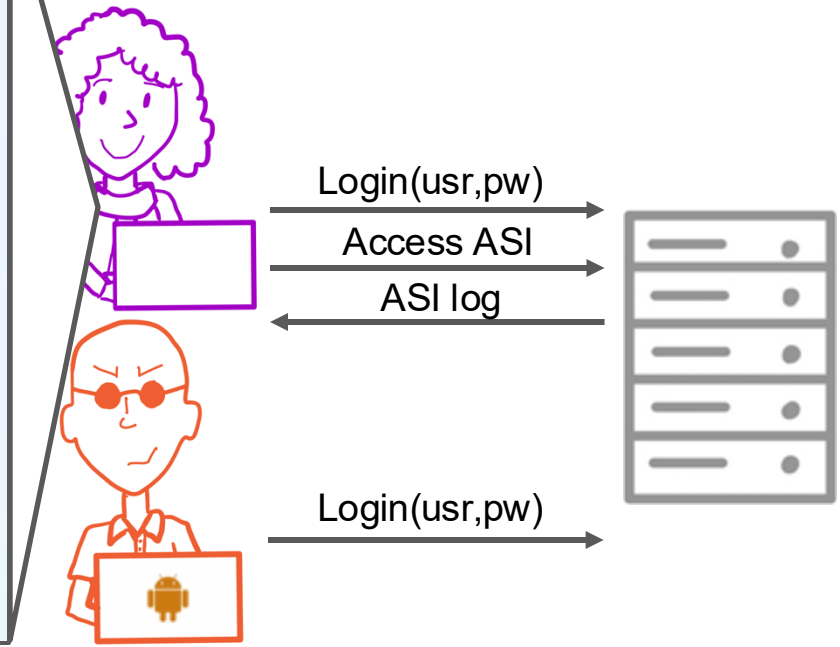

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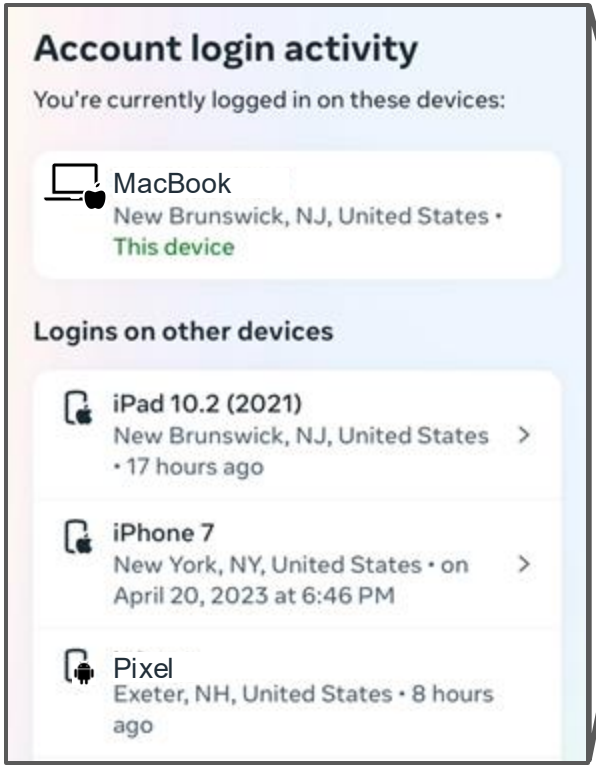

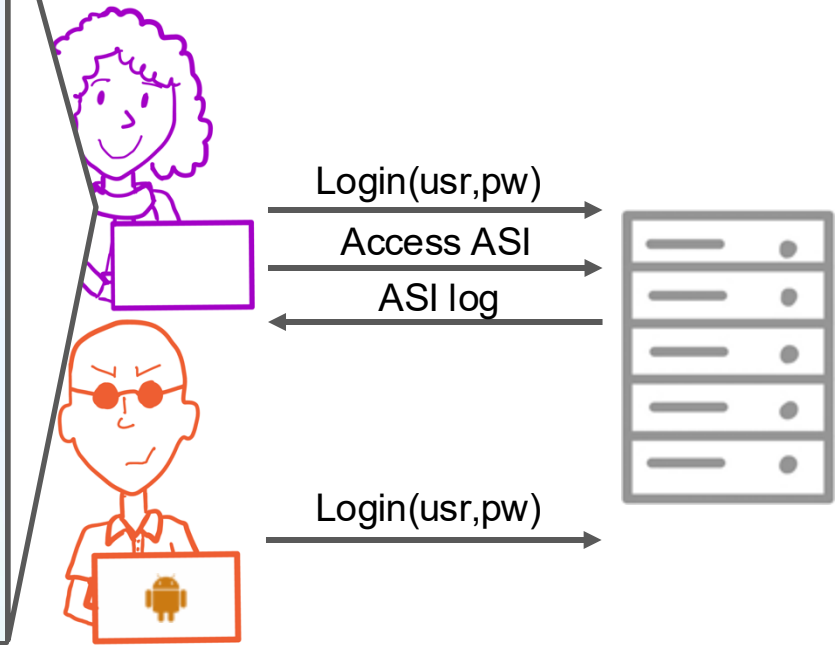

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ASIs critically important for user safety

ASIs are easy to spoof

Account Security Interfaces: Important, Unintuitive, and Untrustworthy. Daffalla et al (2023)

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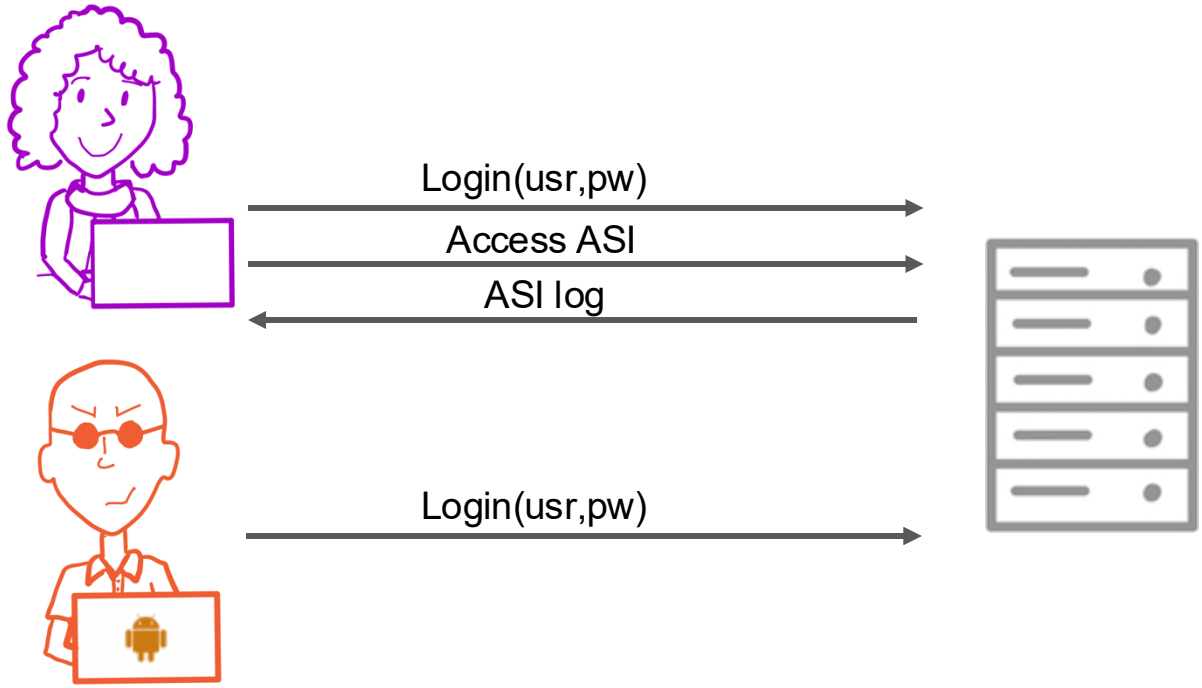

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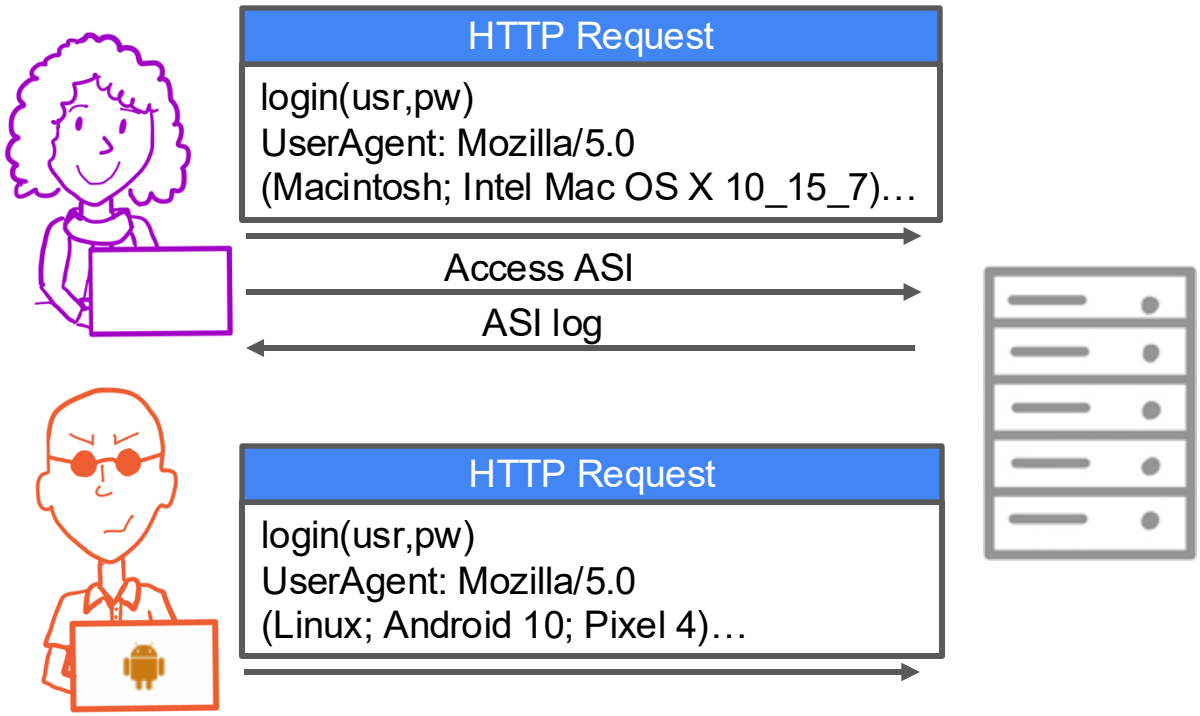

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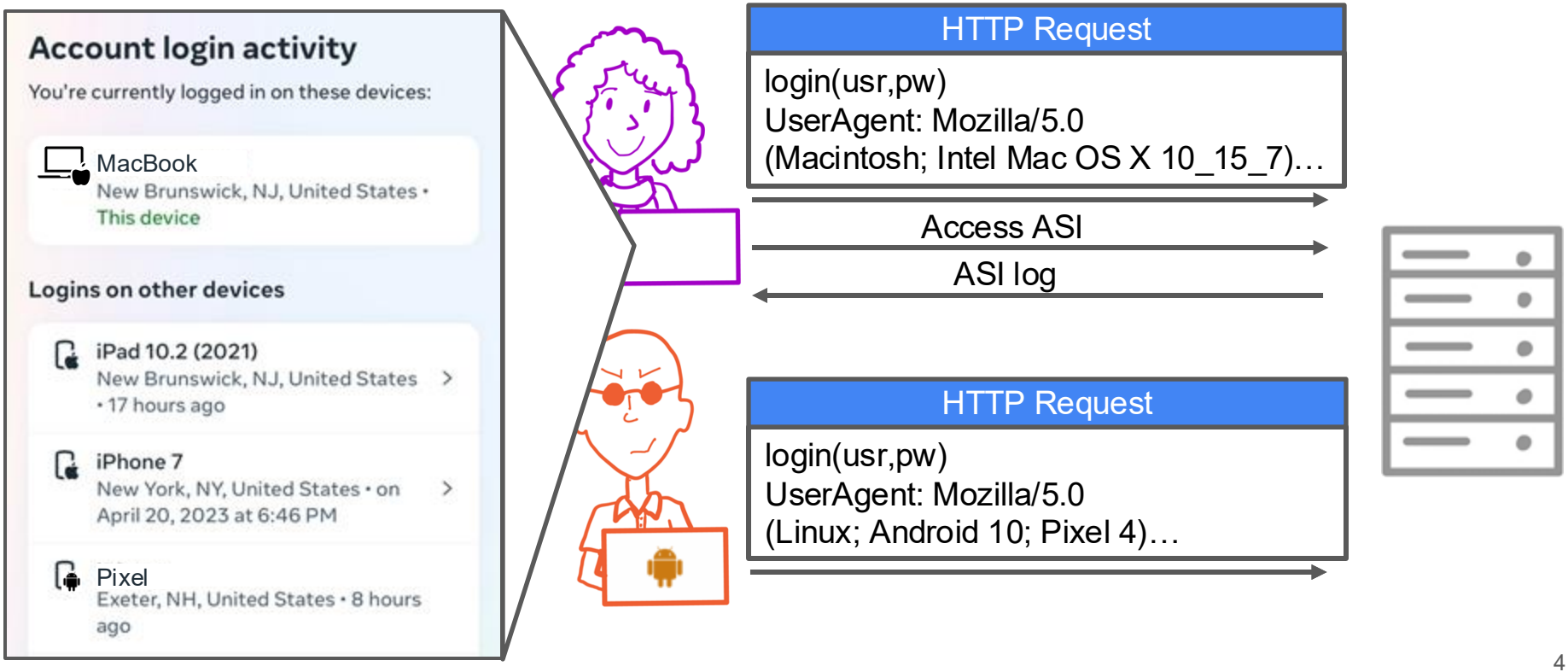

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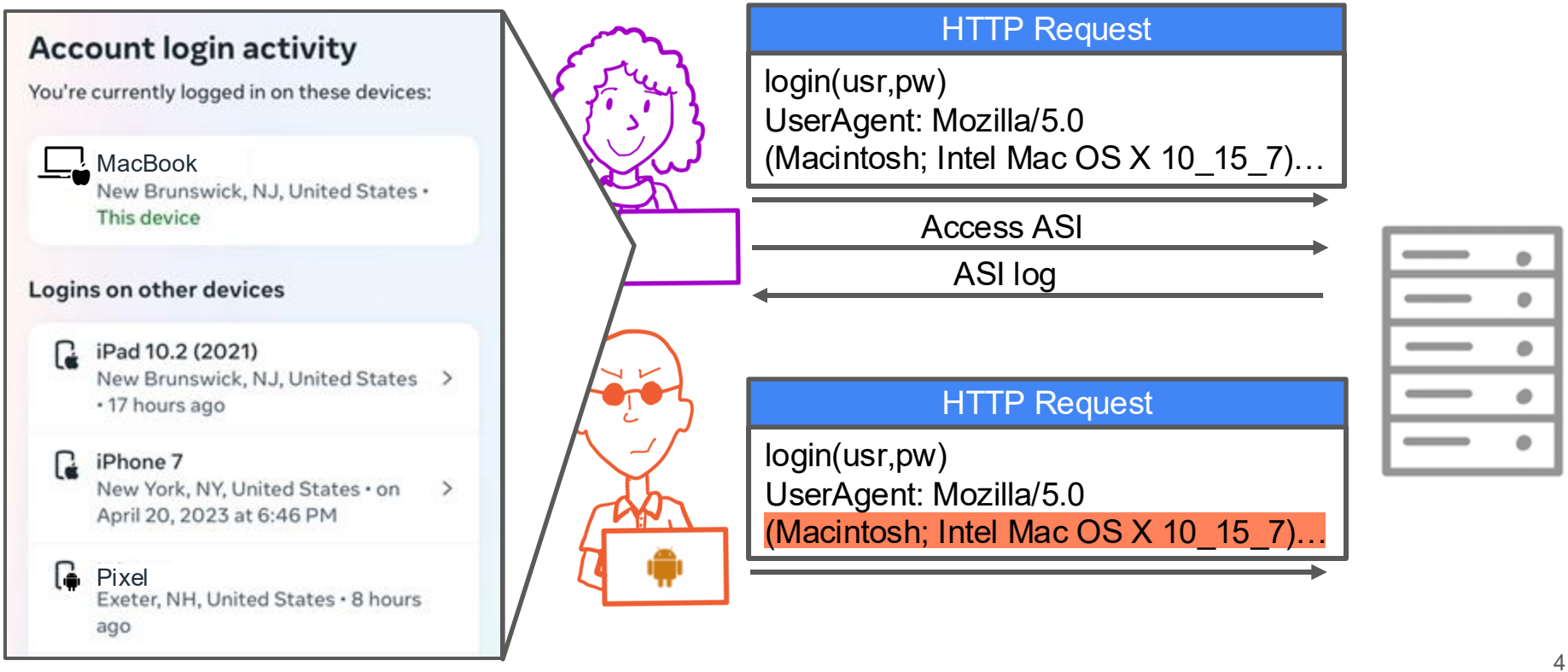

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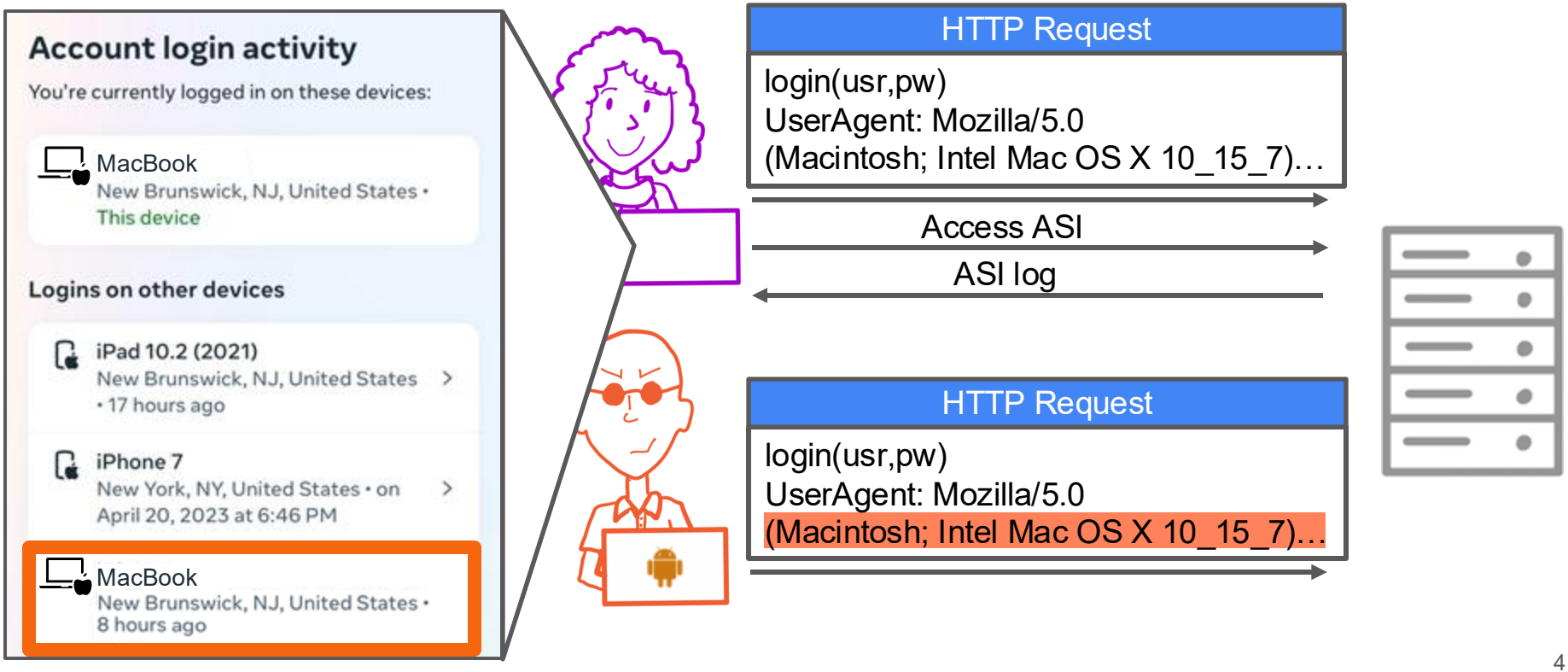

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ASIs integrity is a problem…

…what can we do about it?

Our work: Towards providing ASI integrity

We propose **client-side-encrypted access logging (CSAL)** protocols

- Agnostic to authentication mechanisms
- Do not rely on external services
- Require OS support (browsers are untrusted)

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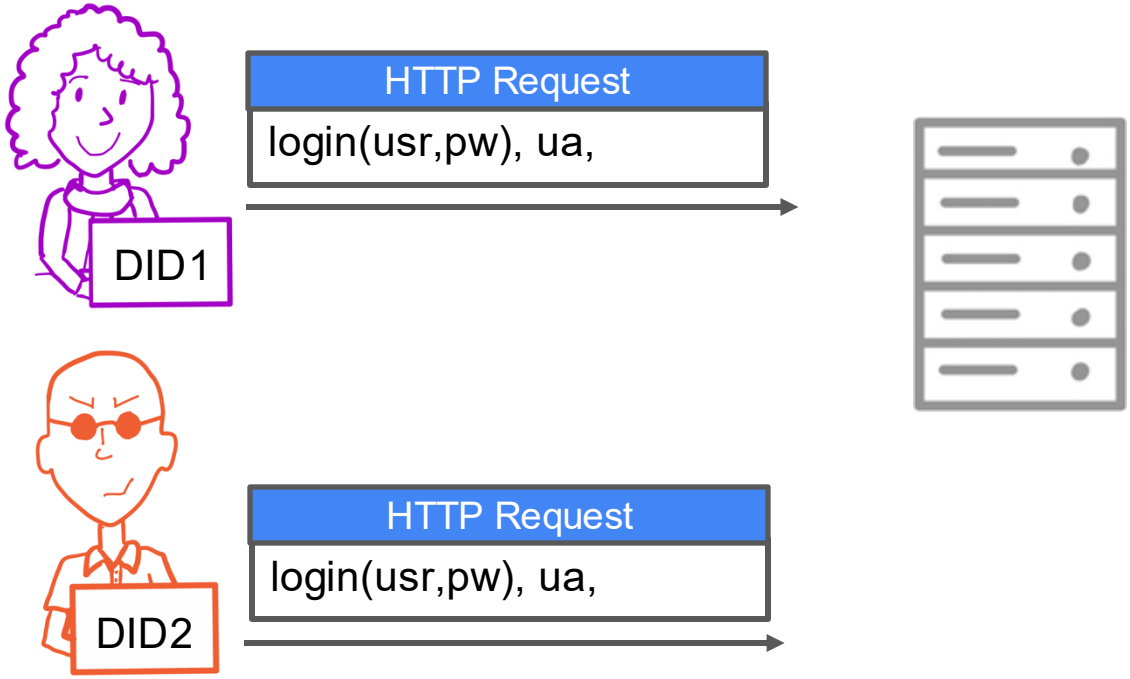
- Require OS support (browsers are untrusted)

In the paper we:

- Formalize CSAL protocols
- Detail a full CSAL protocol and formally analyze it
- Proof-of-concept CSAL implementation and deployment considerations

Straw approach: Adding reliable OS-provided information



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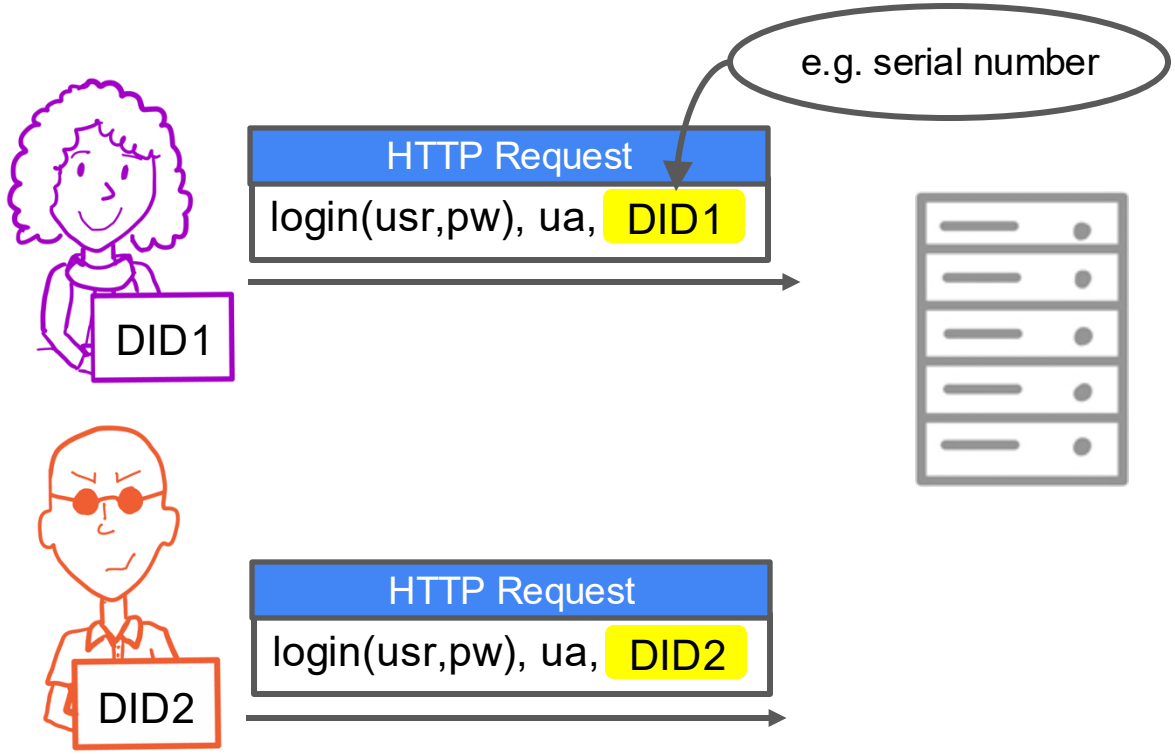

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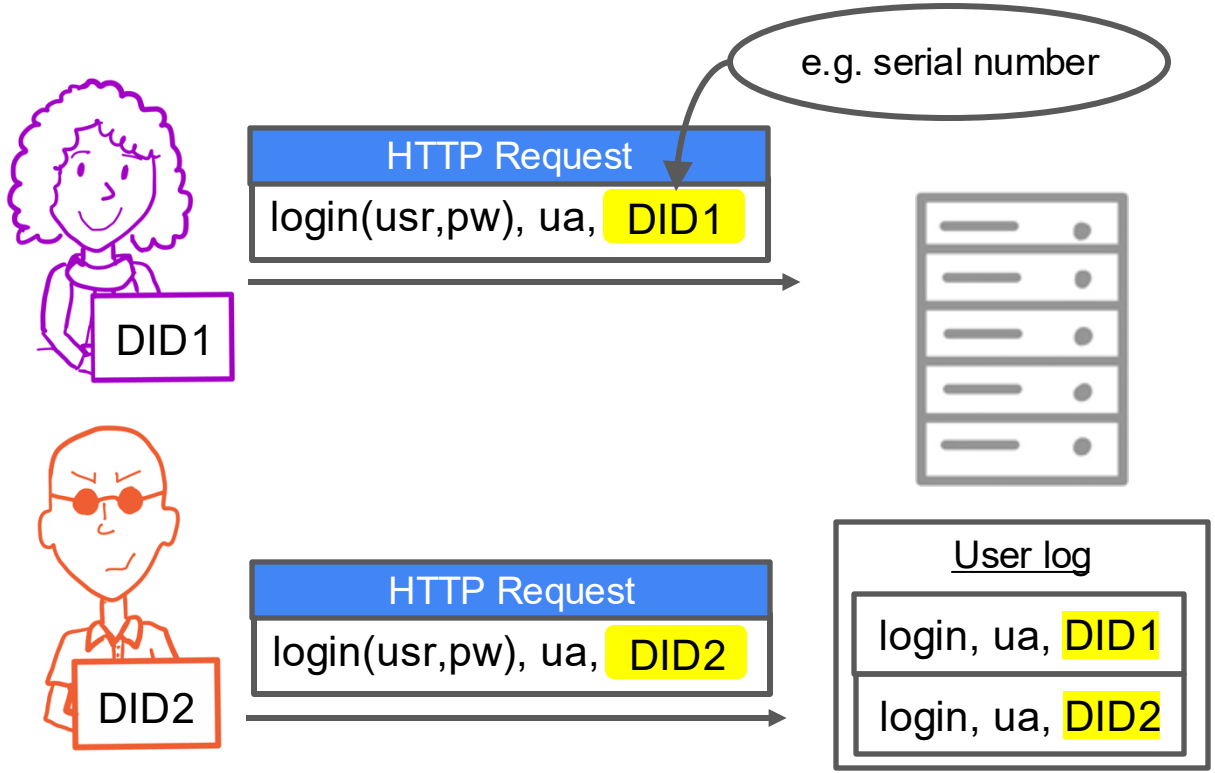

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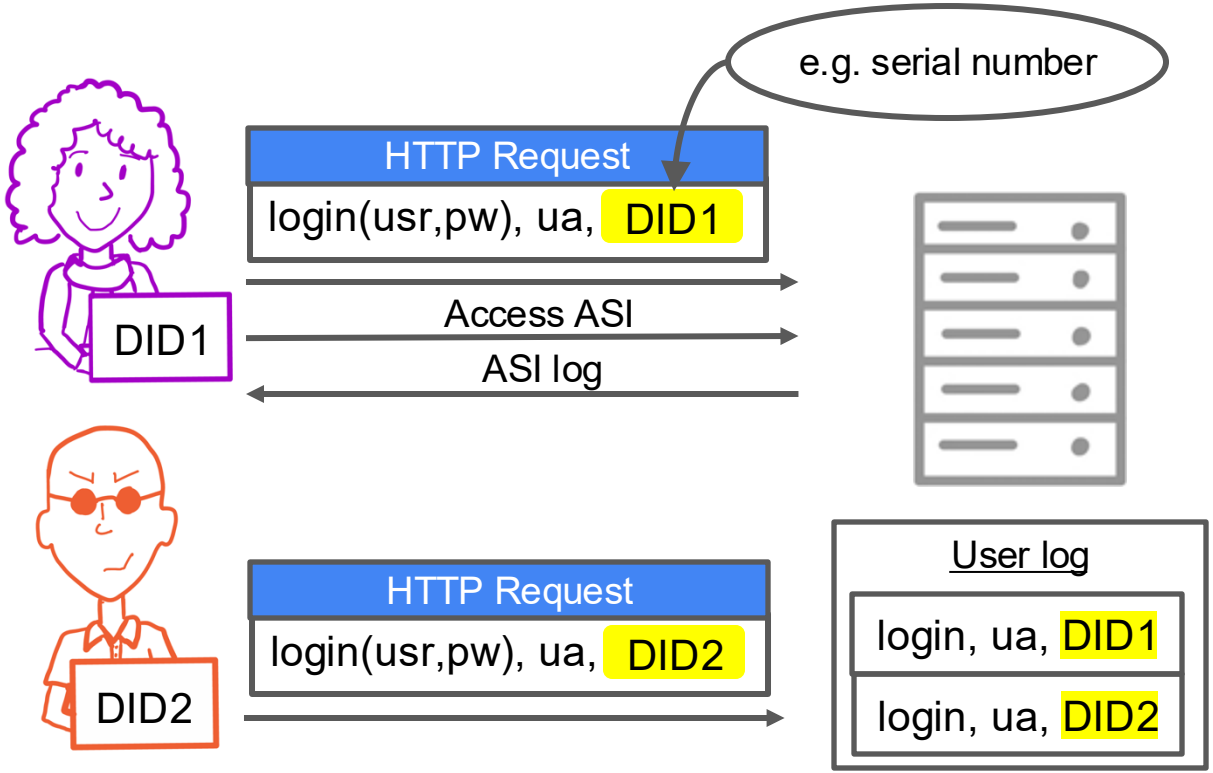

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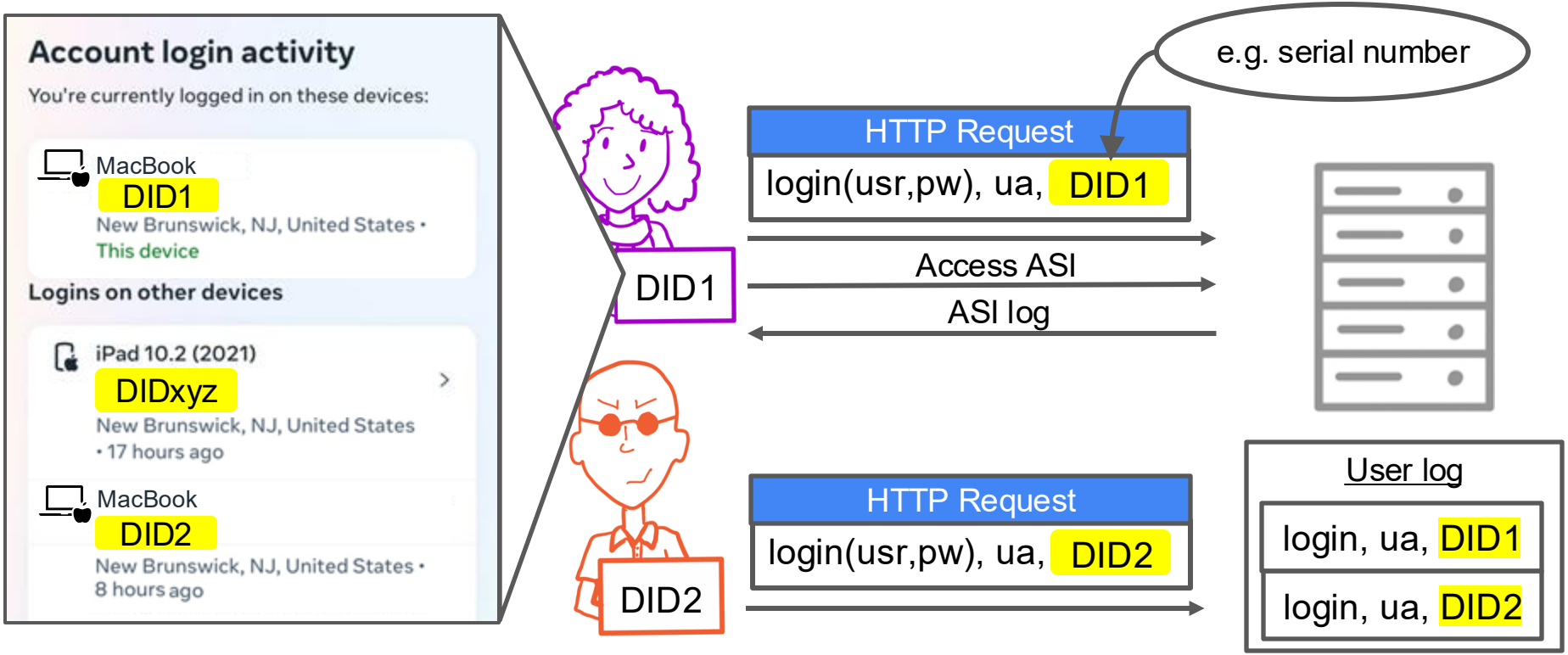

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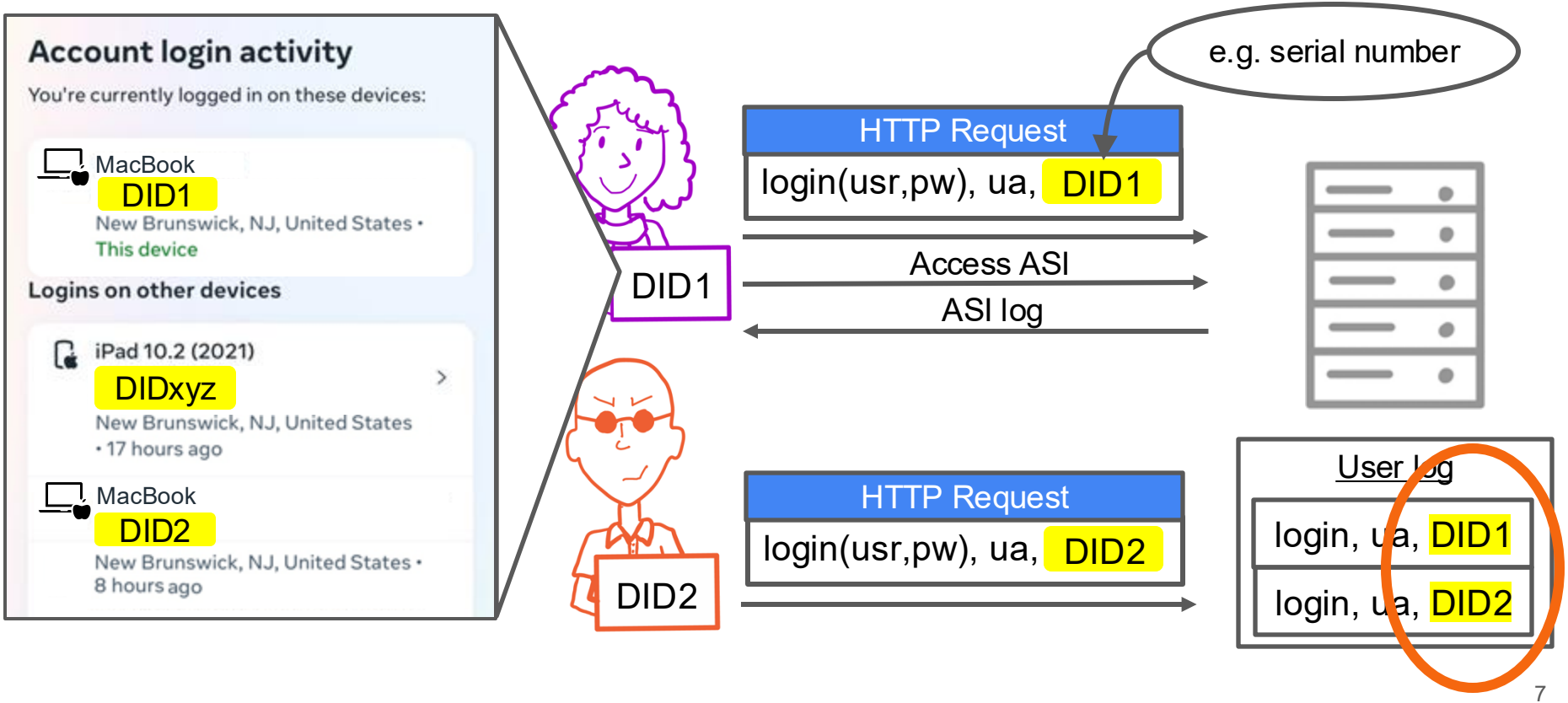

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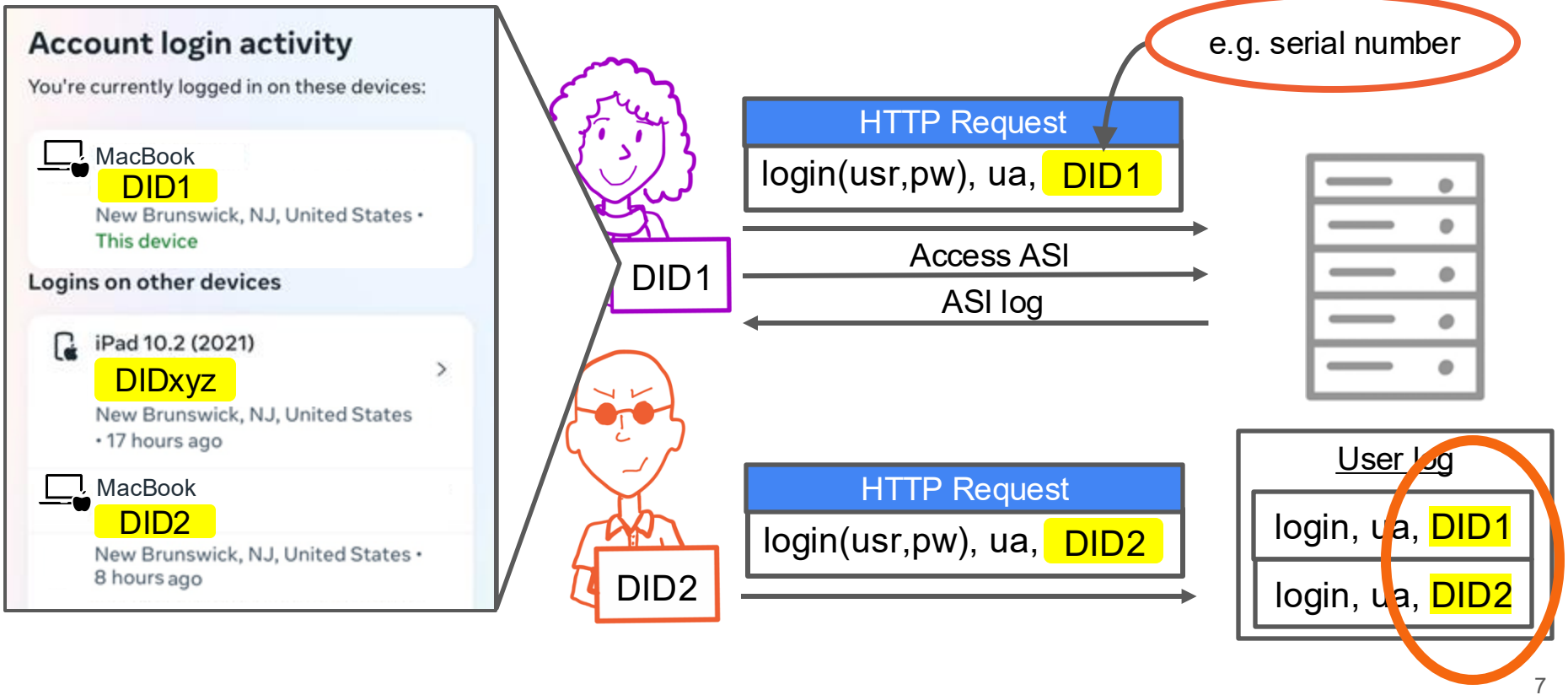

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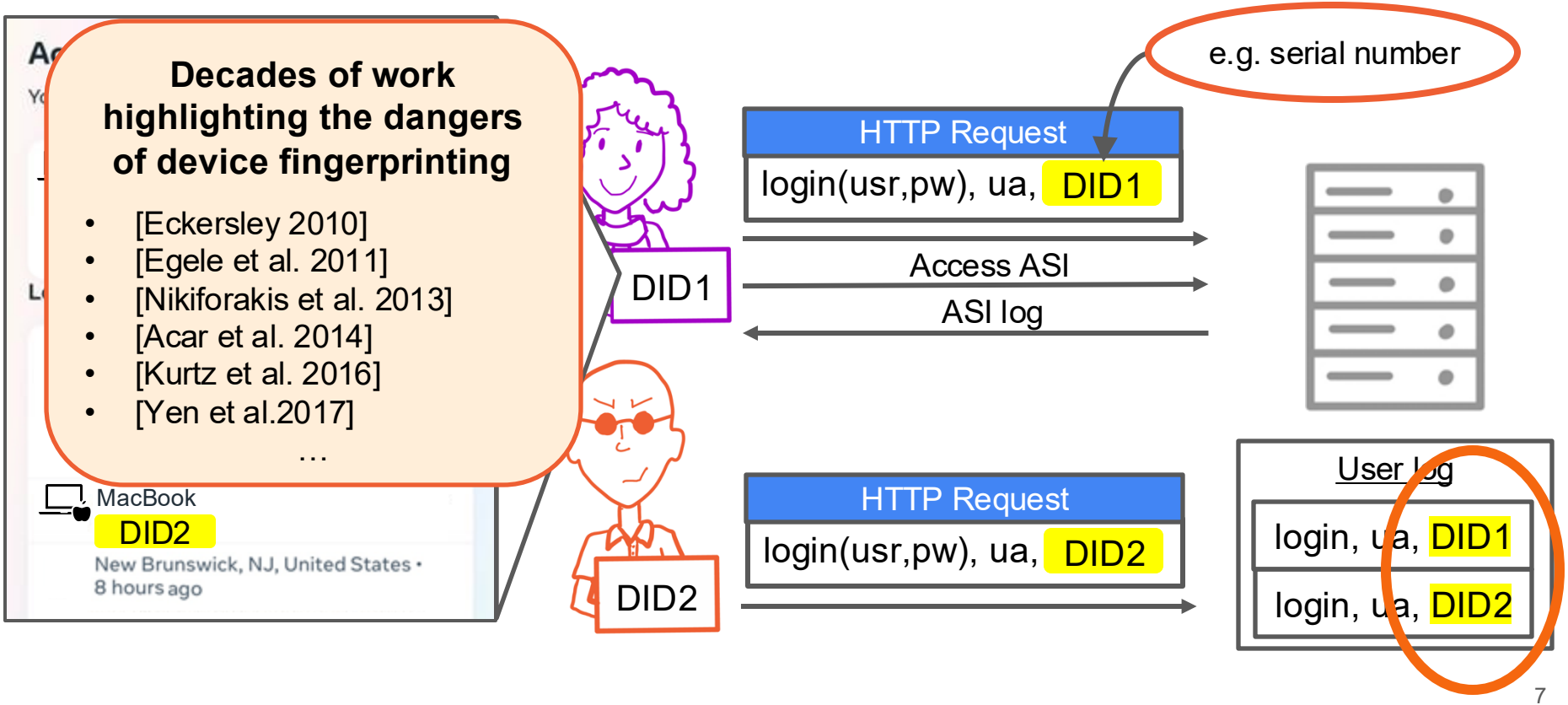

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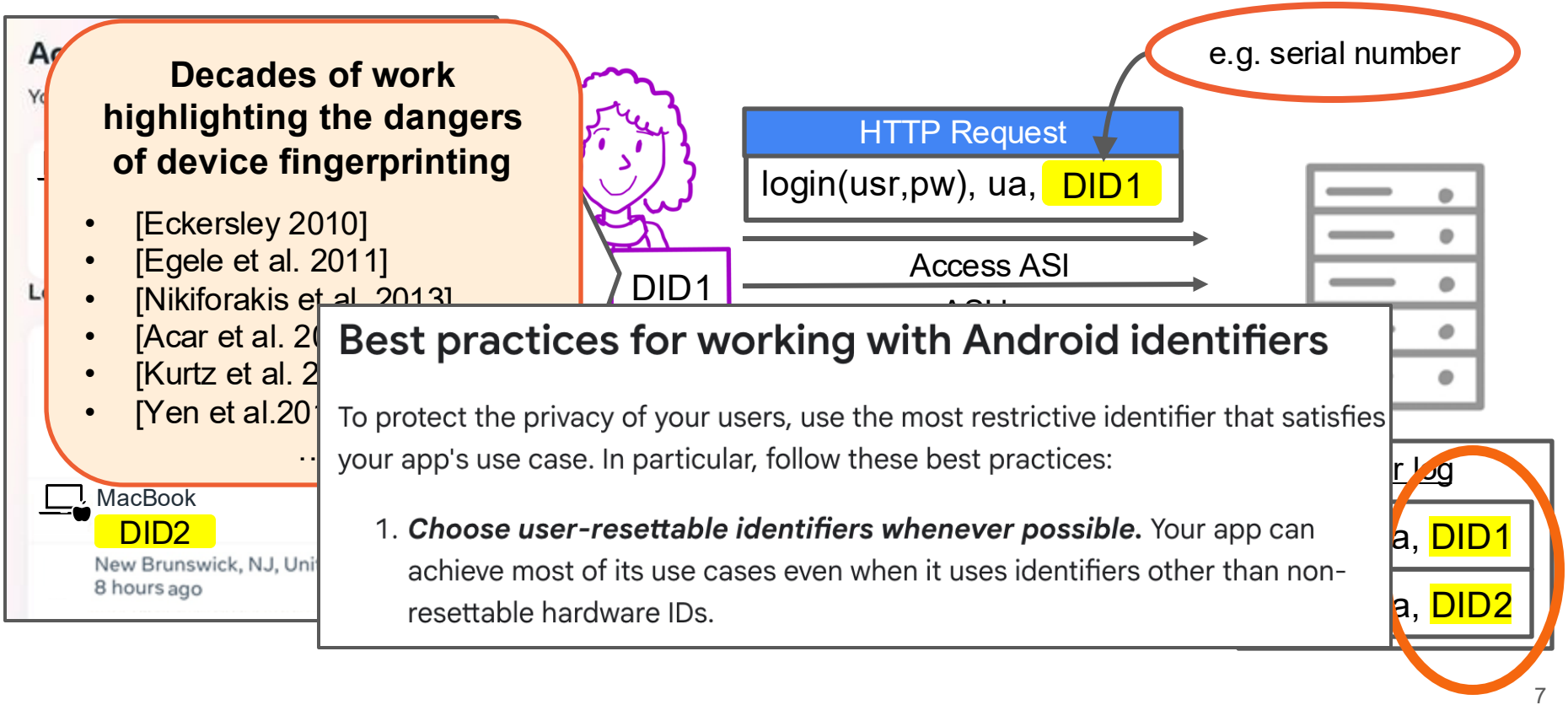

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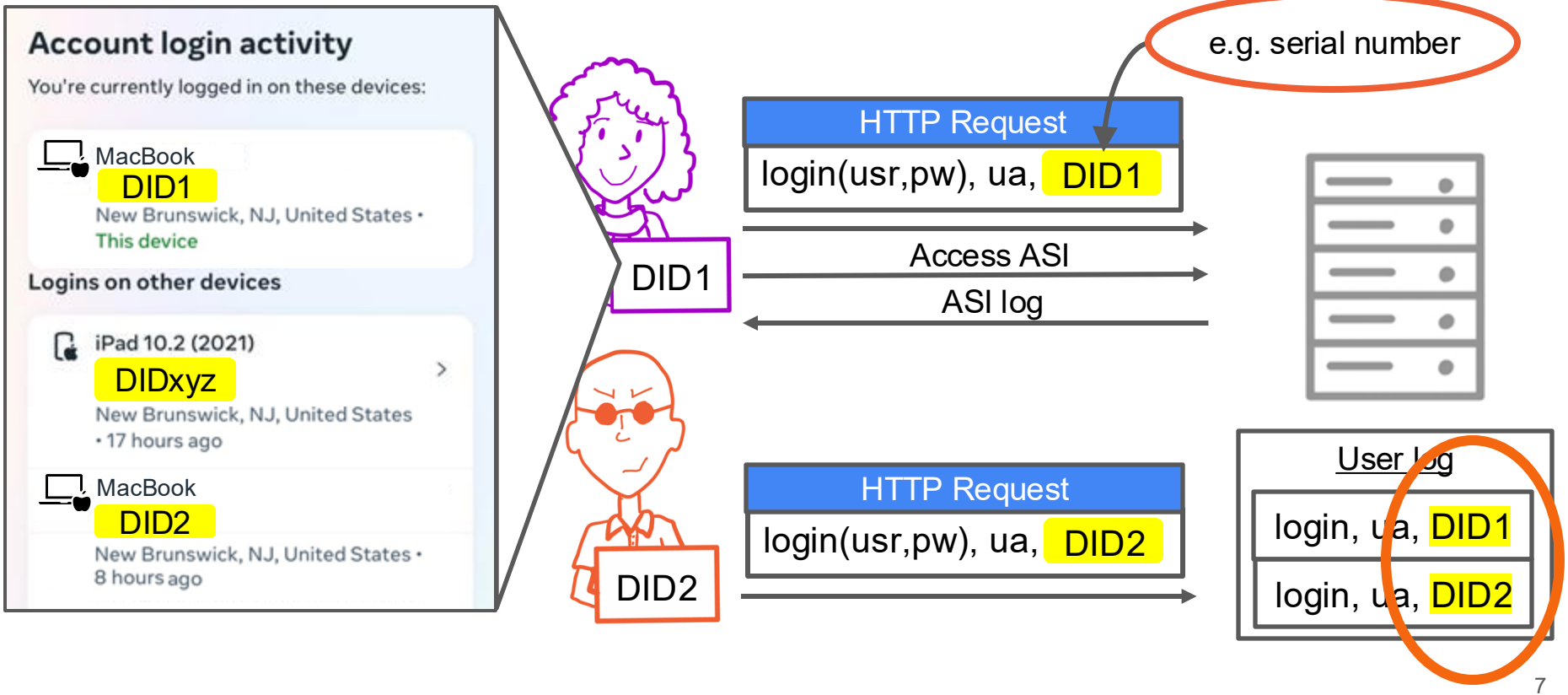

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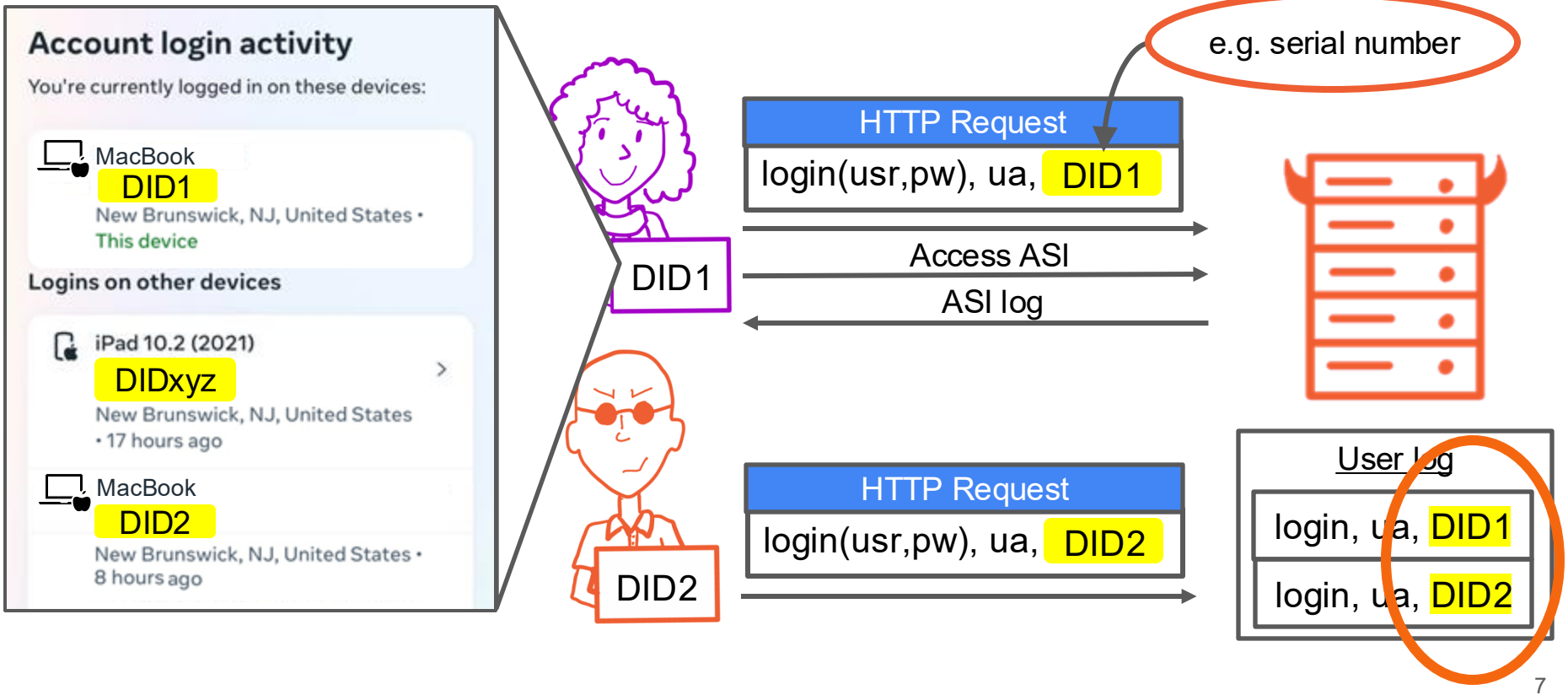

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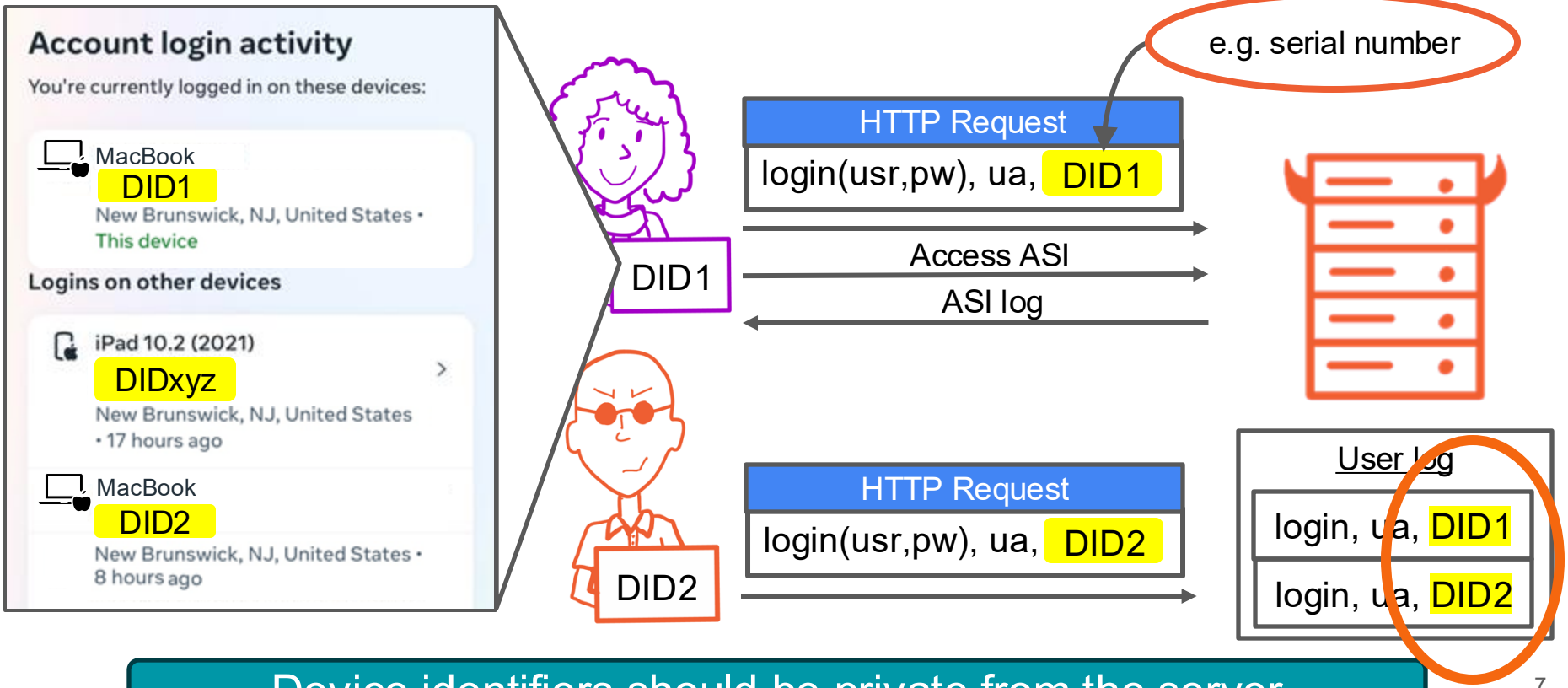
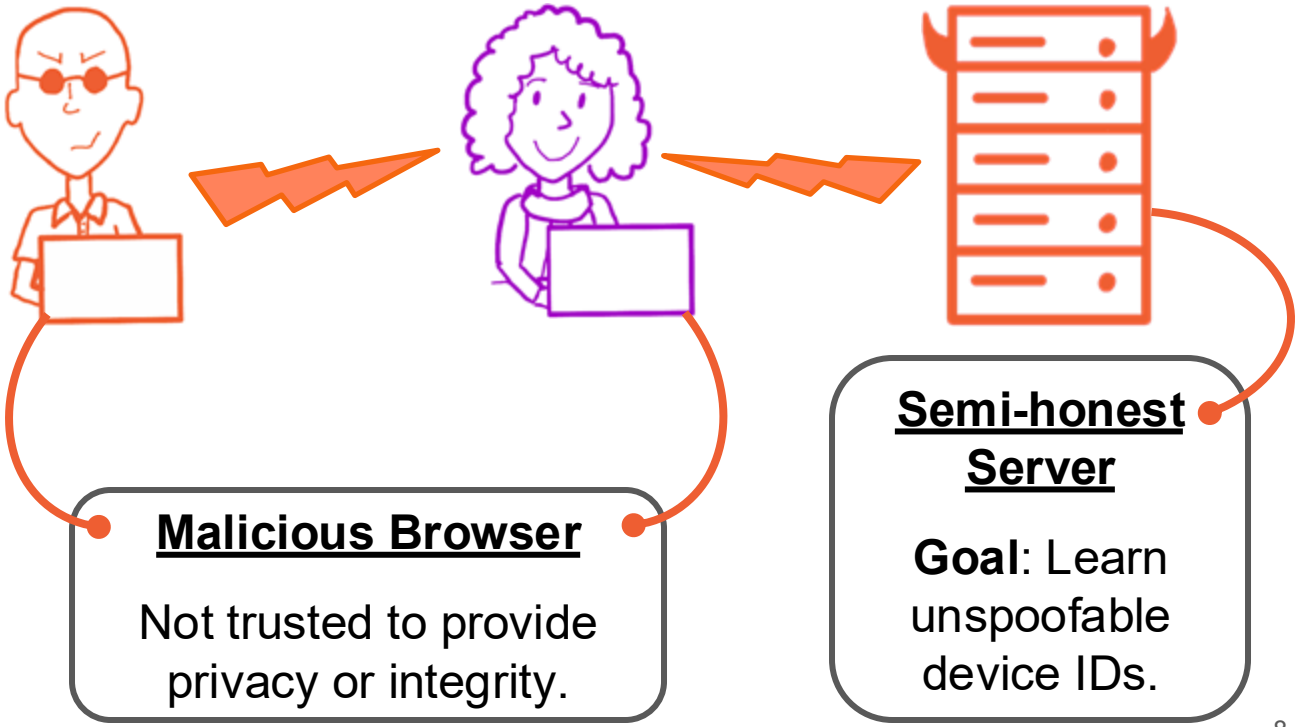


Providing attribution and privacy

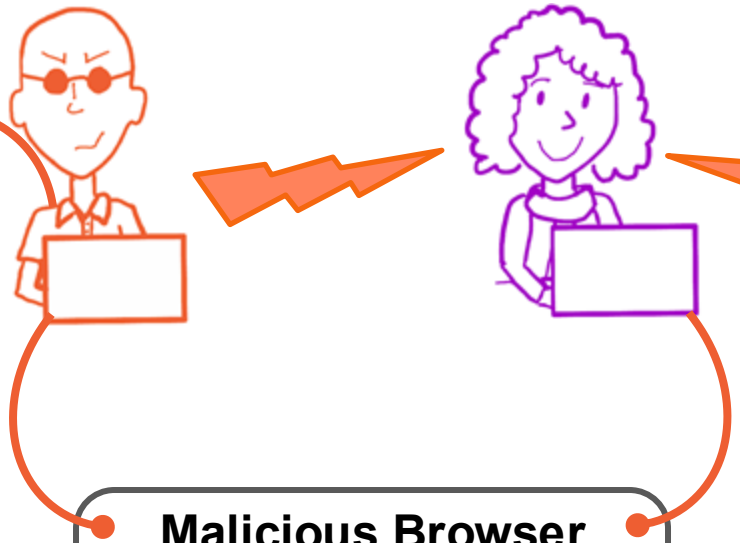


Providing attribution and privacy

Malicious User

Goal: Tamper with/circumvent log entries

*Can authenticate as the user.



Malicious Browser

Not trusted to provide privacy or integrity.

Semi-honest Server

Goal: Learn unspoofable device IDs.

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Encrypt & sign in the OS

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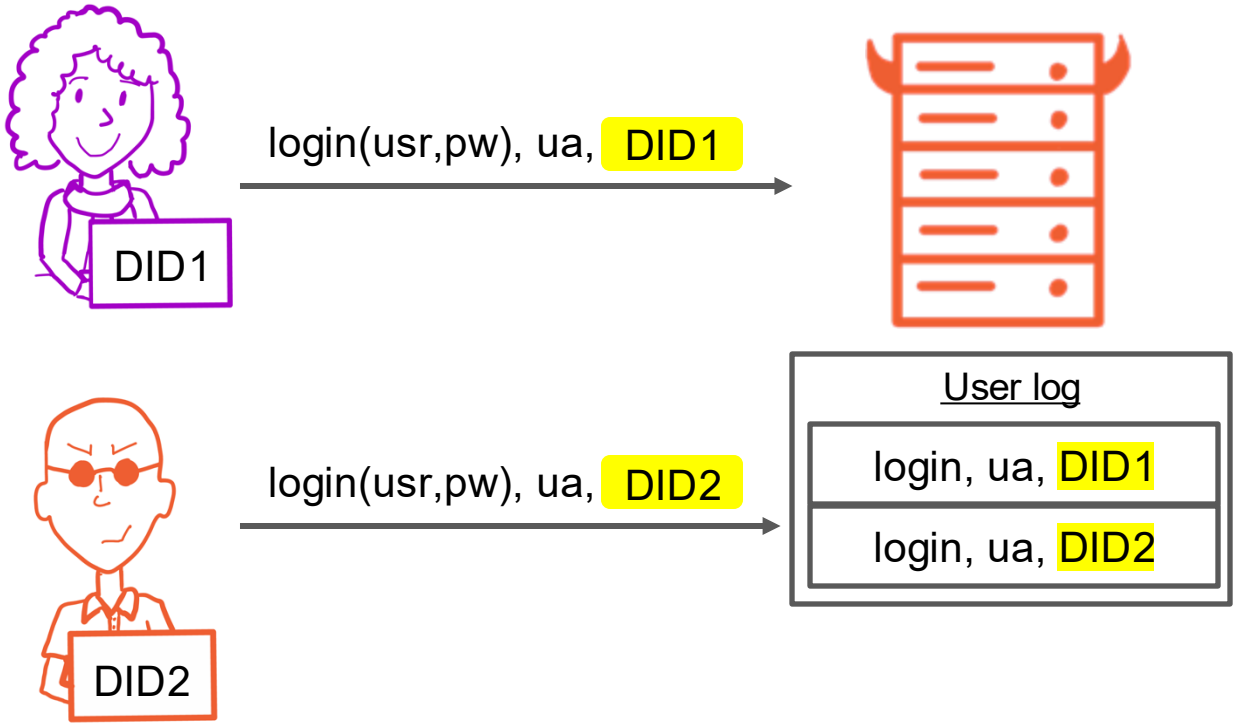

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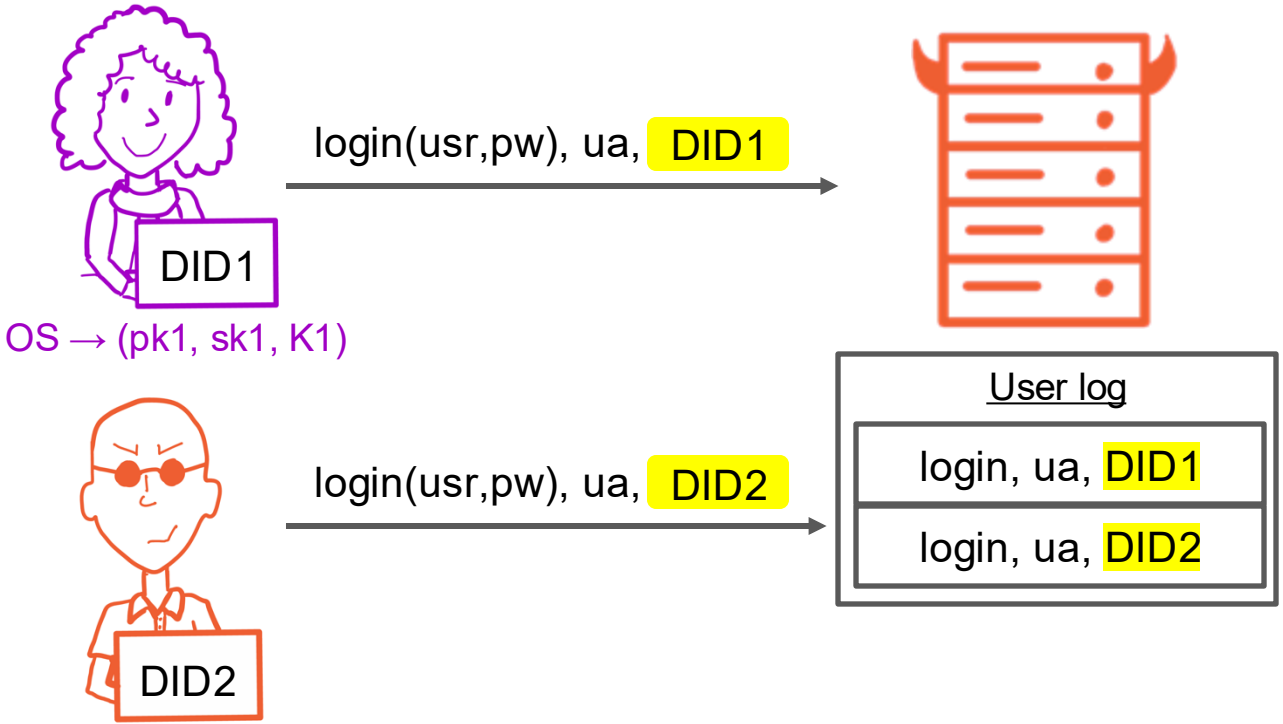

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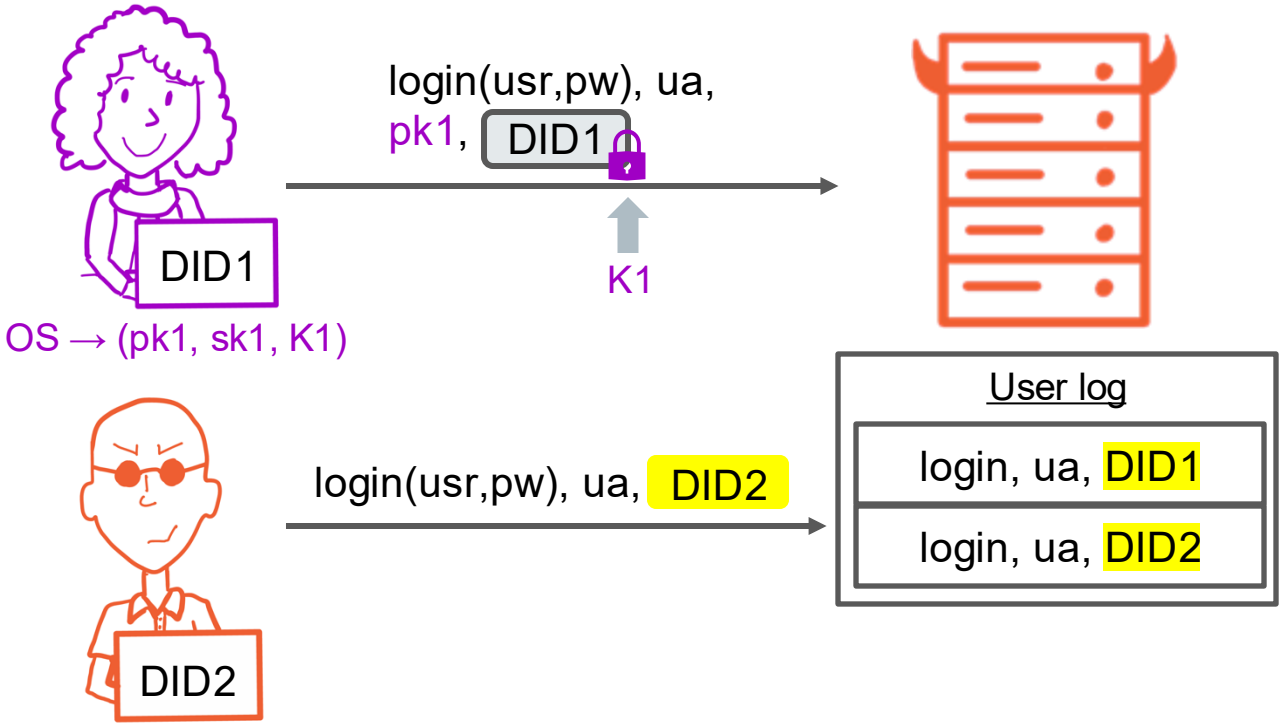

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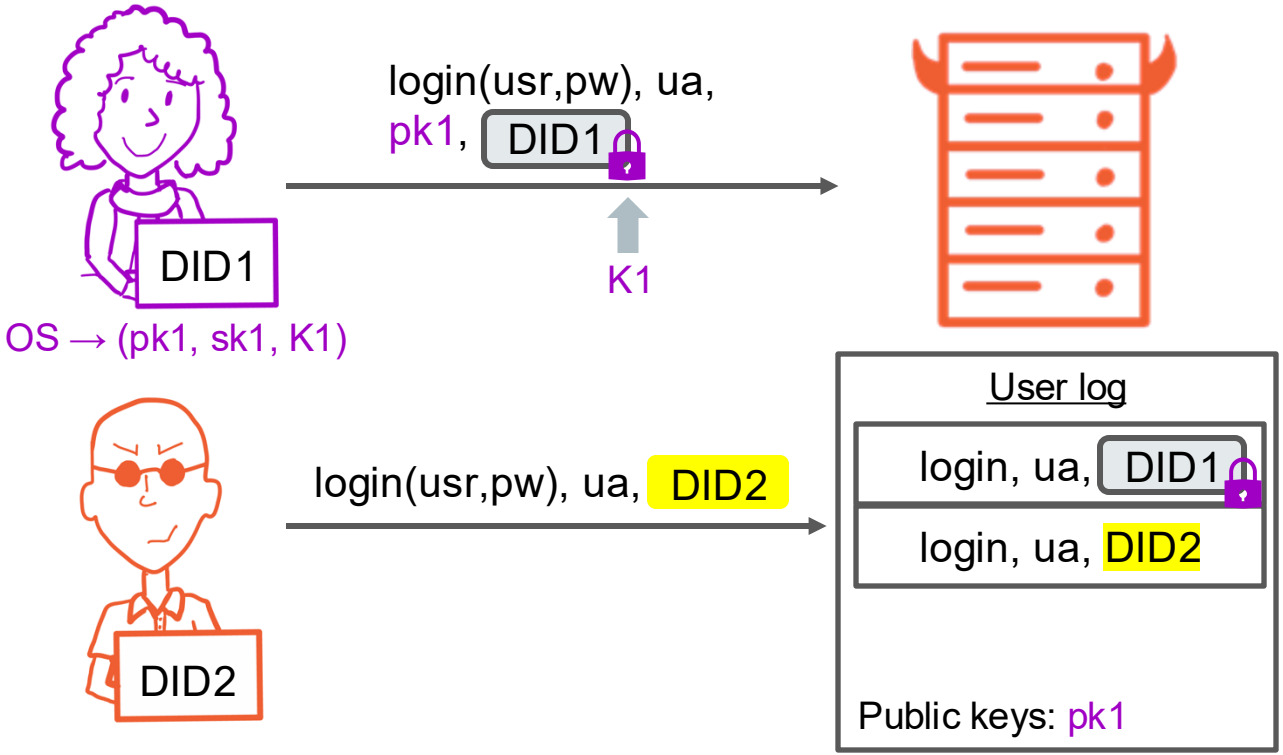

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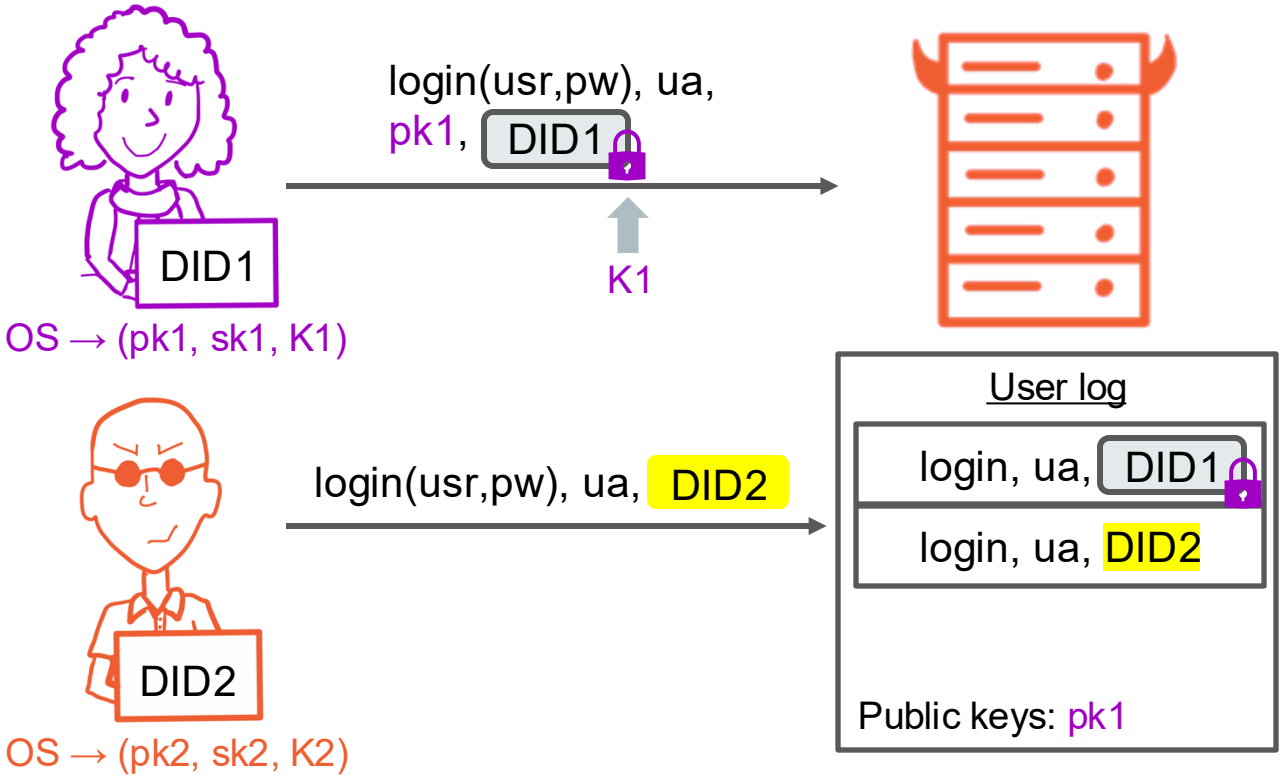

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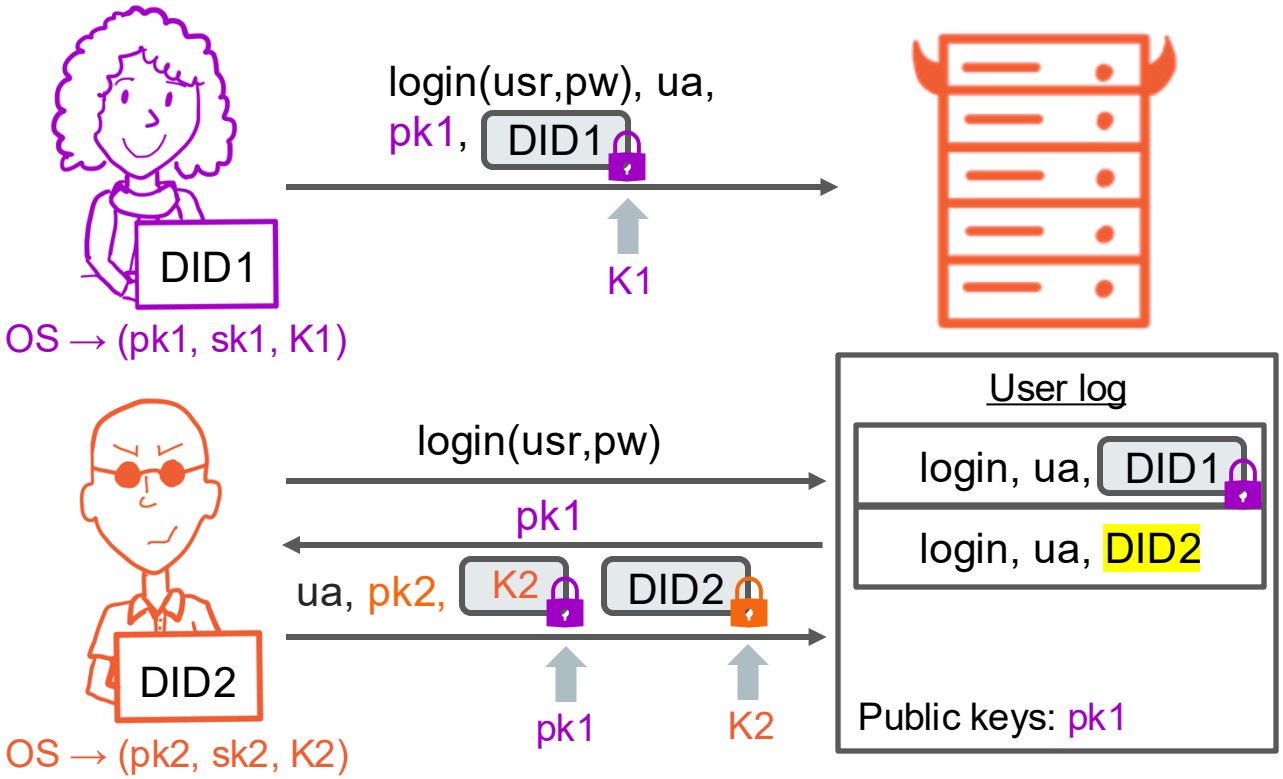

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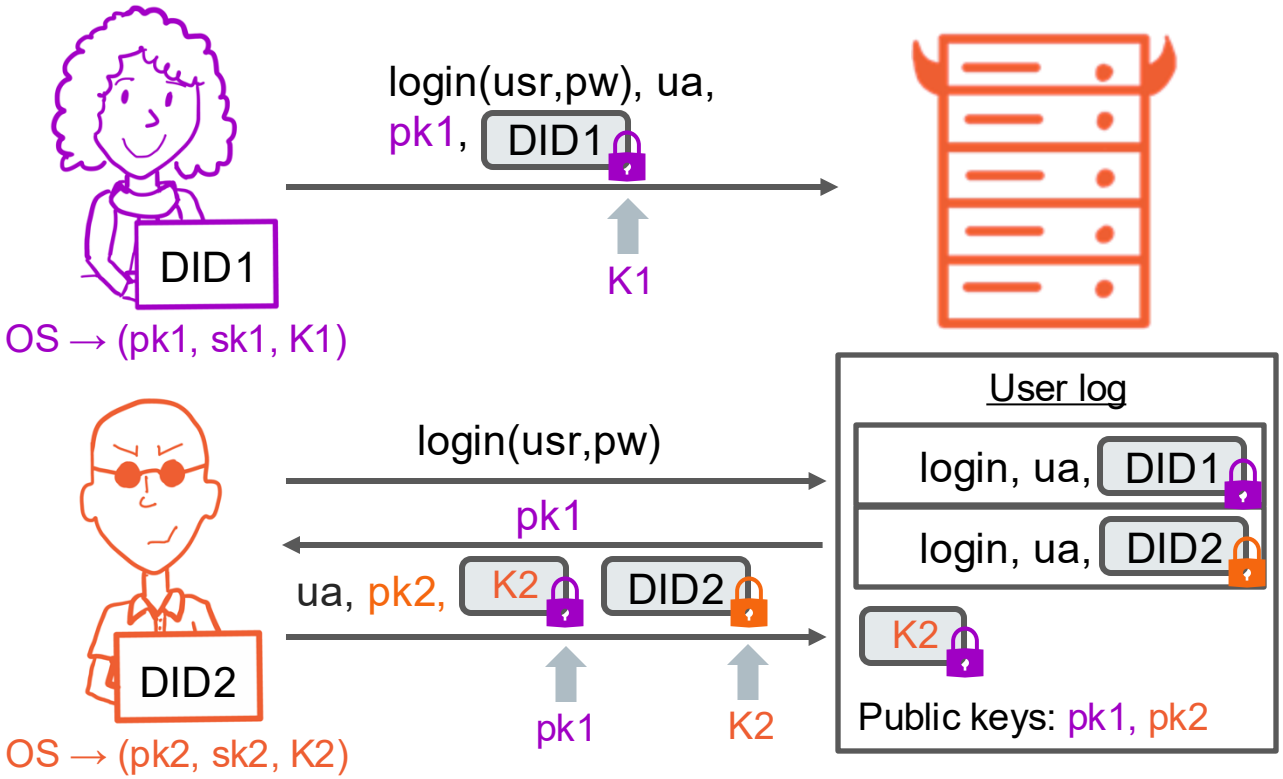

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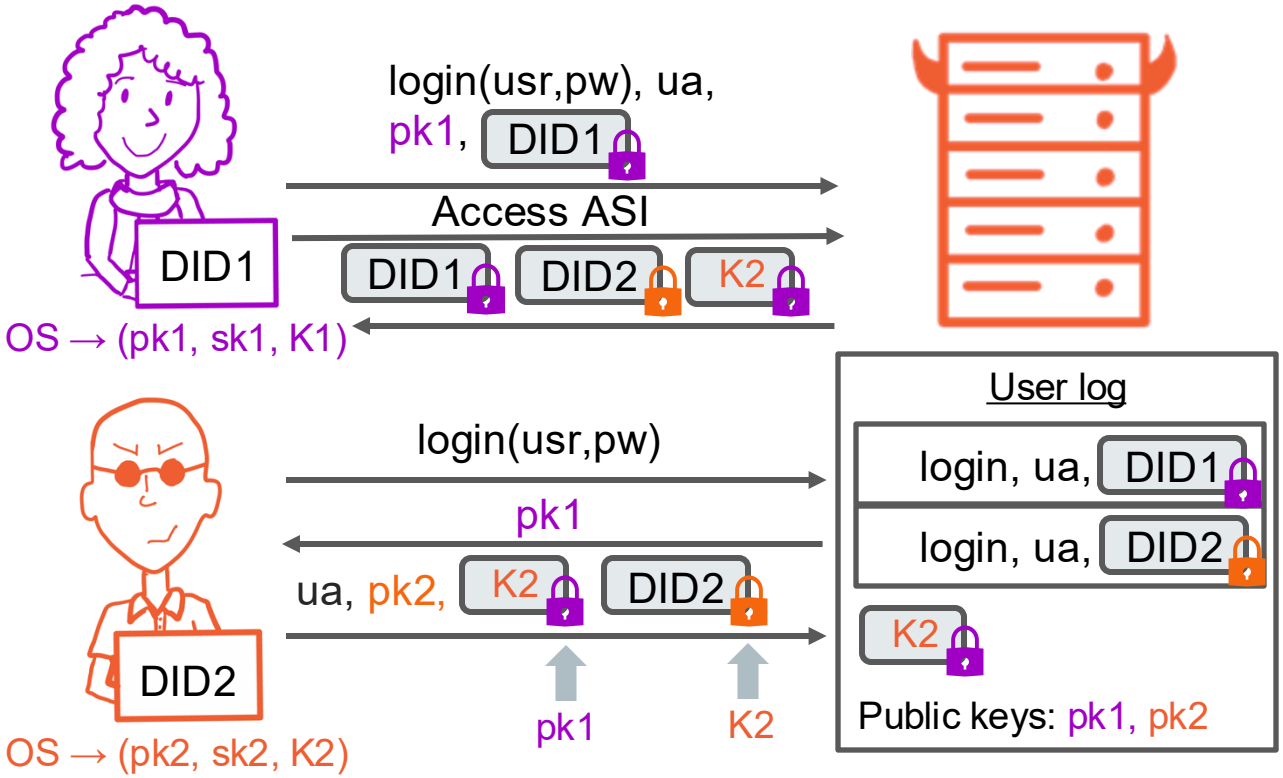

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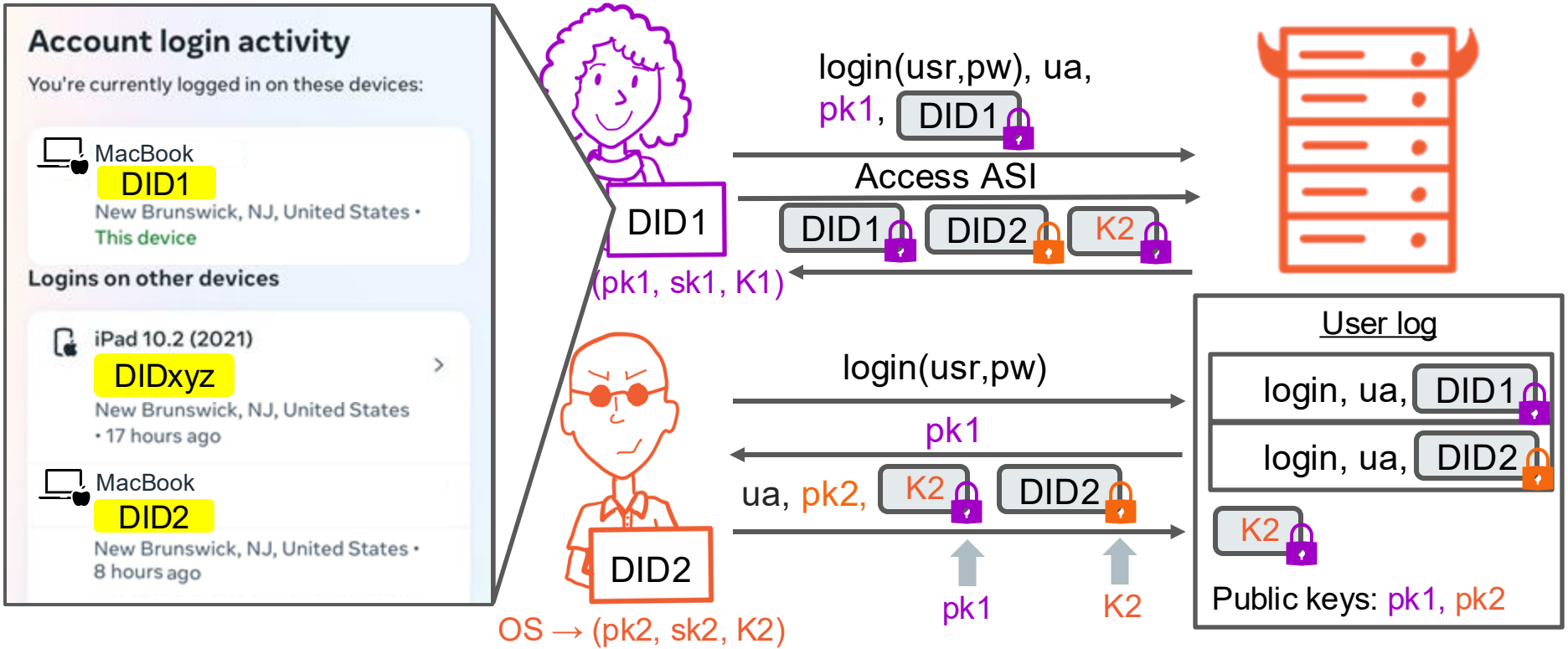

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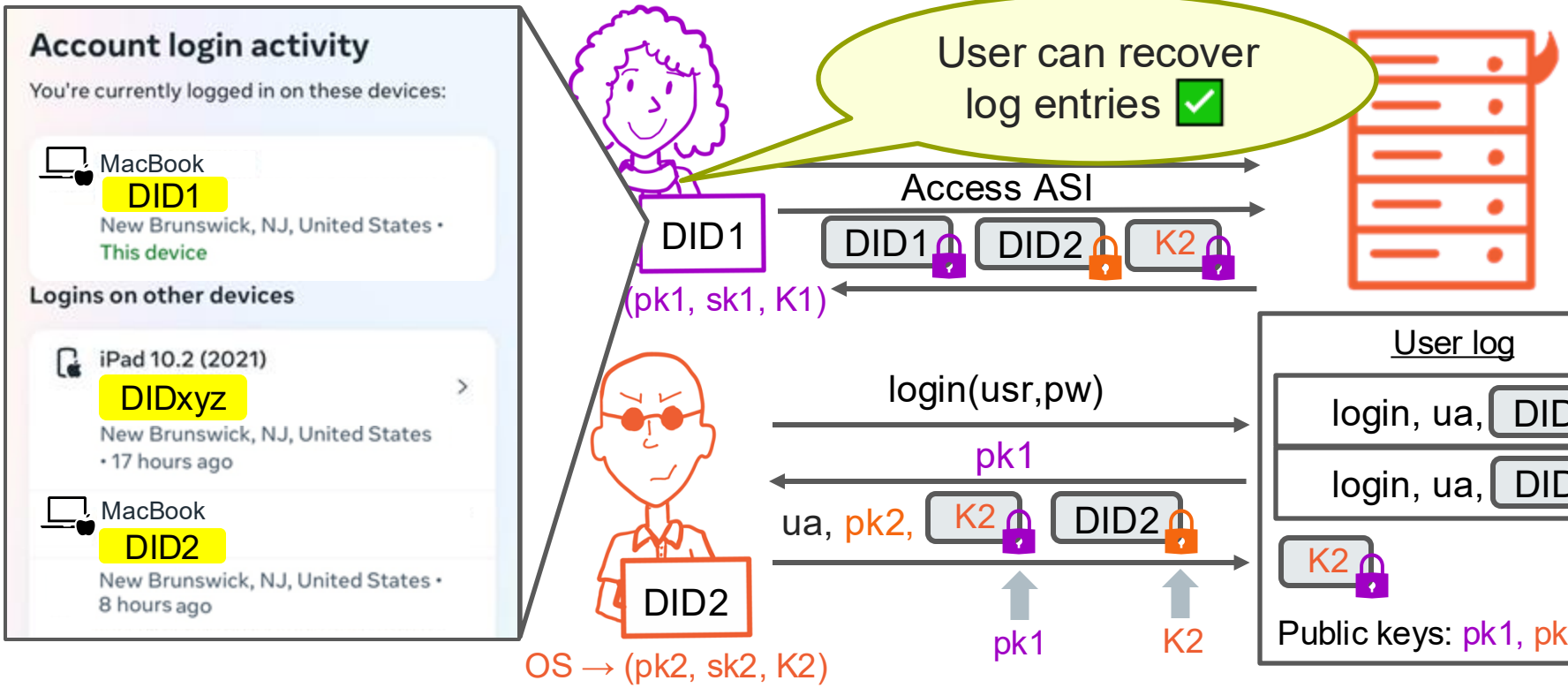

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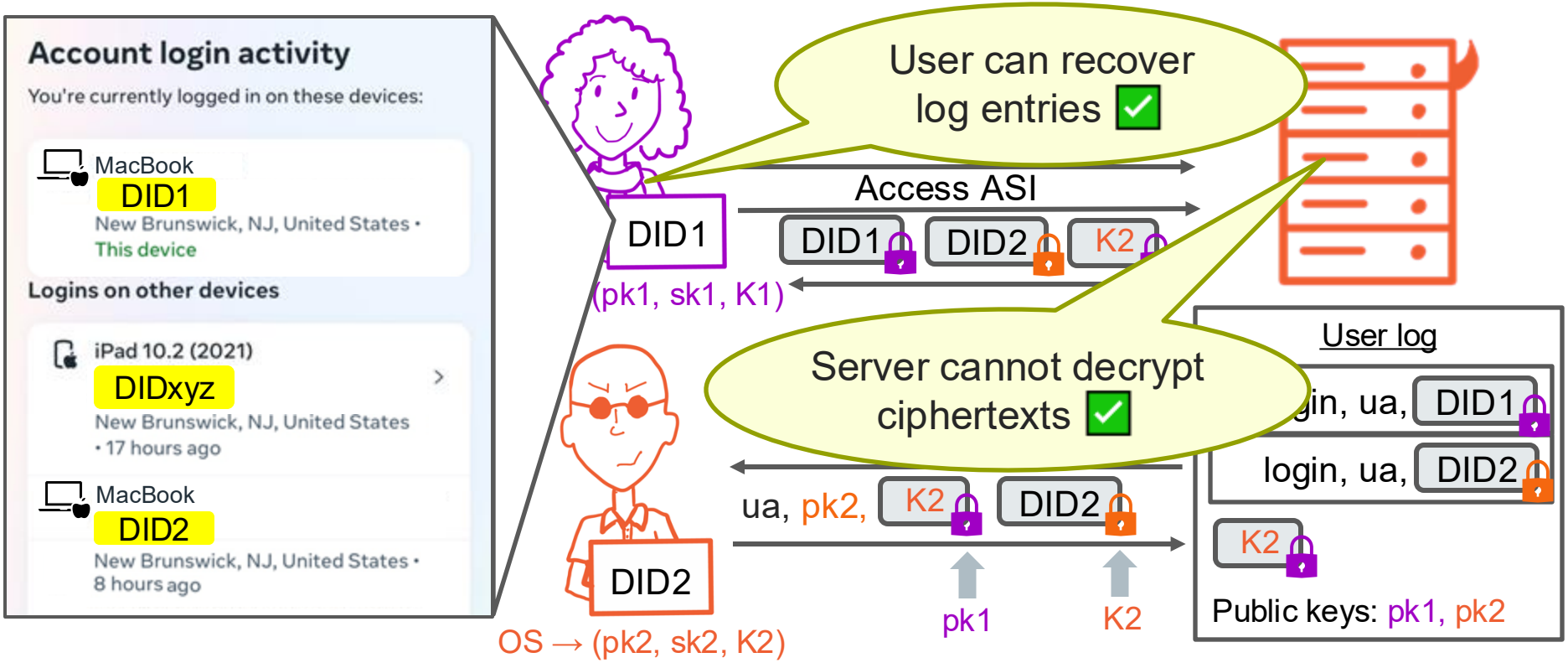

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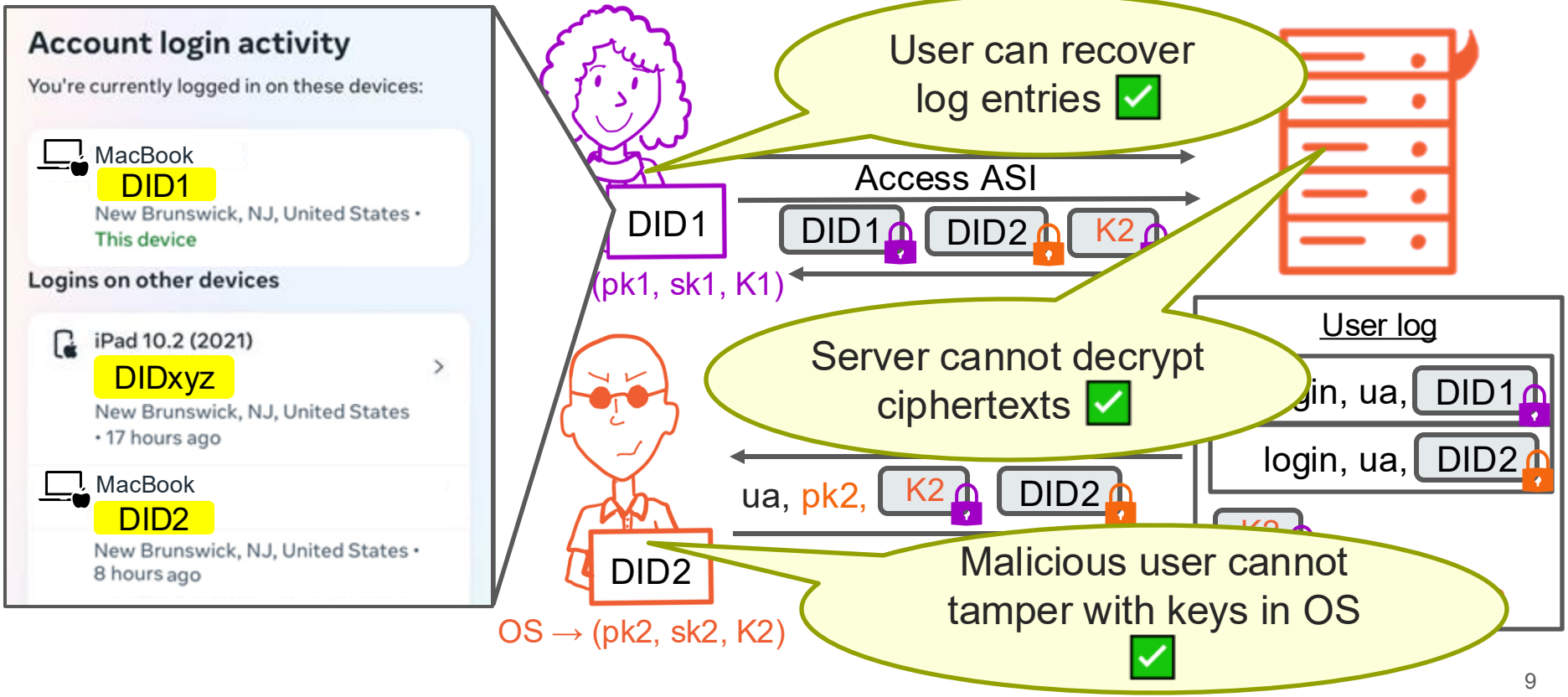
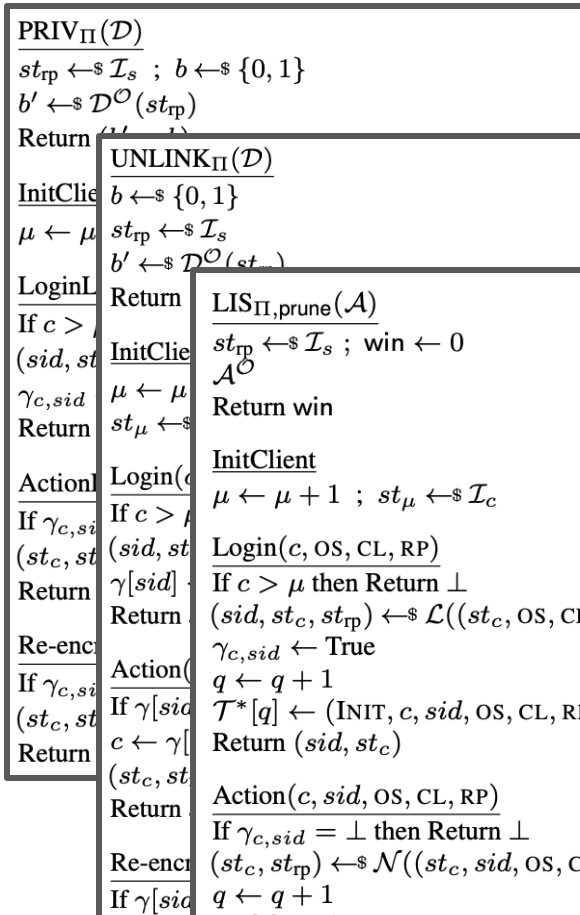


Formal treatment of CSAL

- **Log privacy** and **session unlinkability** against server
- **“Ability to access”** log entries



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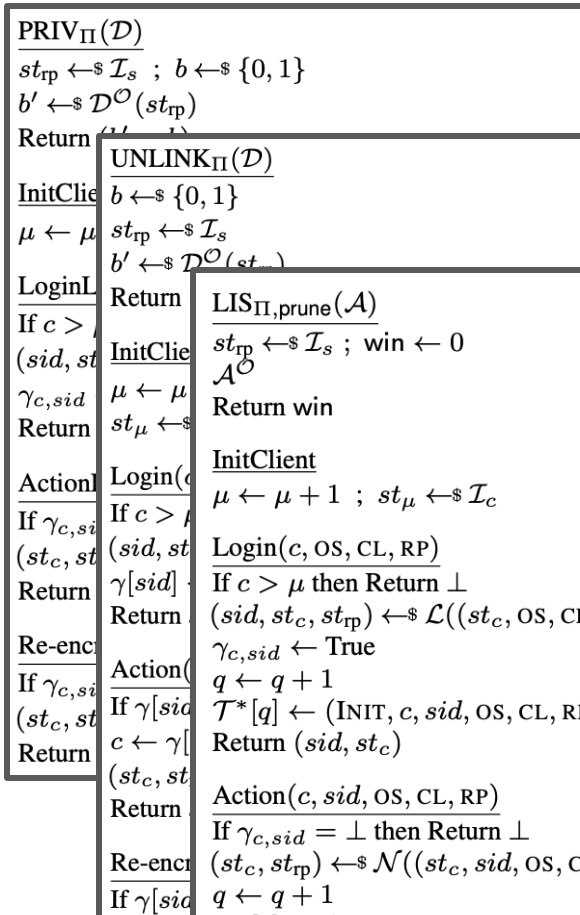

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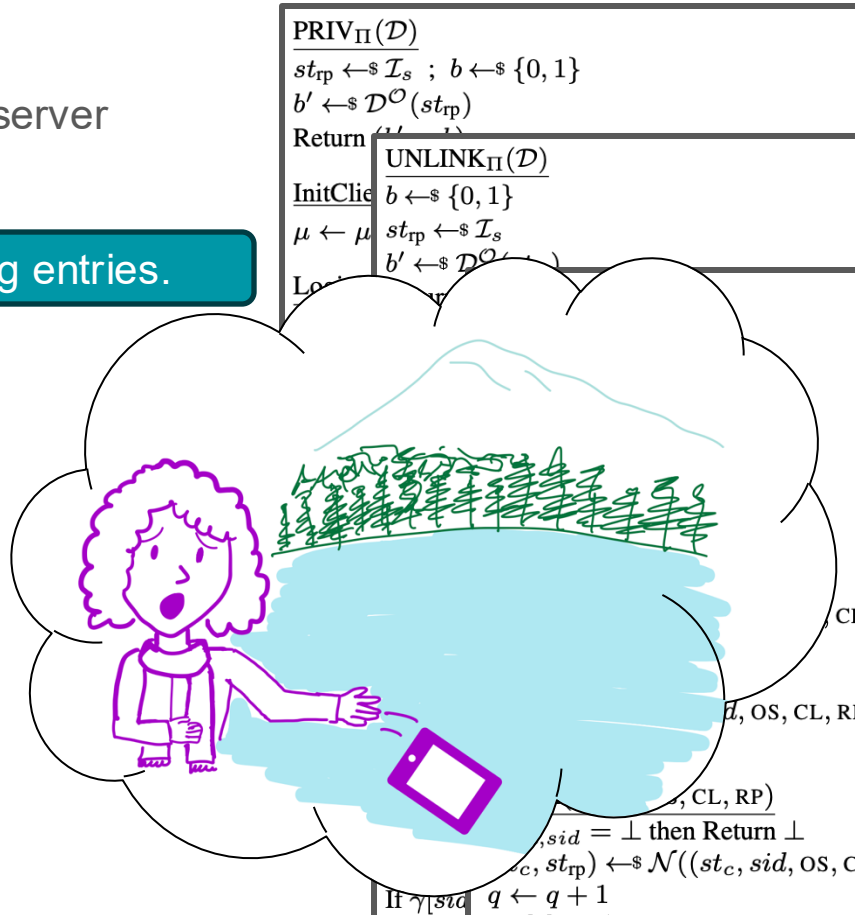

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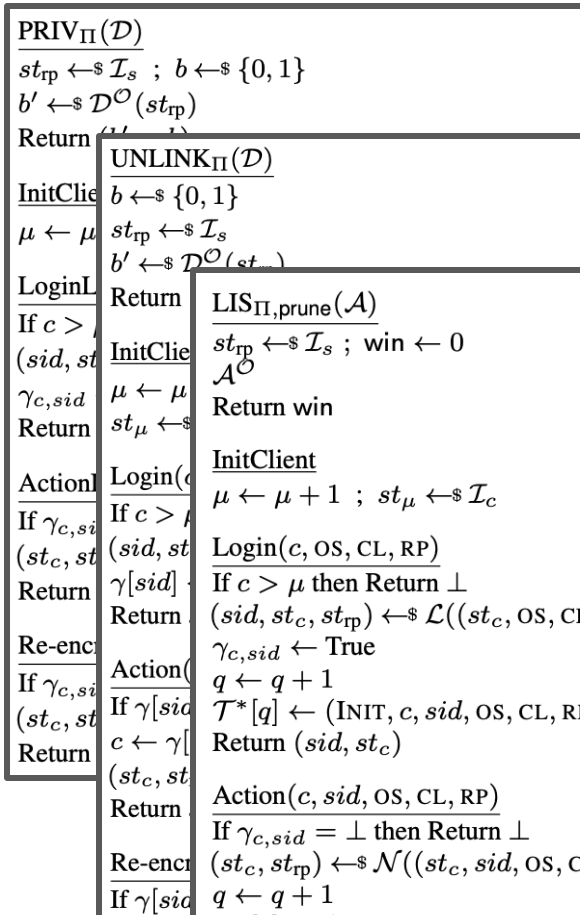

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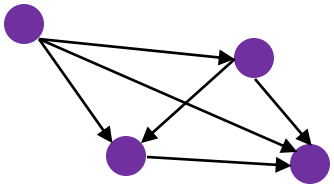

- Define reachability graph to characterize ciphertext access

$\underline{\text{PRIV}_{\Pi}(\mathcal{D})}$
$st_{\text{rp}} \leftarrow\!\$\ \mathcal{I}_s\ ;\ b \leftarrow\!\$\ \{0,1\}$
$b' \leftarrow\!\$\ \mathcal{D}^{\mathcal{O}}(st_{\text{rp}})$
Return

$\underline{\text{UNLINK}_{\Pi}(\mathcal{D})}$
$b \leftarrow\!\$\ \{0,1\}$
$st_{\text{rp}} \leftarrow\!\$\ \mathcal{I}_s$
Return

$\underline{\text{LIS}_{\Pi,\text{prune}}(\mathcal{A})}$
$st_{\text{rp}} \leftarrow\!\$\ \mathcal{I}_s\ ;\ \text{win} \leftarrow 0$
$\mathcal{A}^{\mathcal{O}}$
Return win

$\underline{\text{InitClient}}$
$\mu \leftarrow \mu + 1\ ;\ st_{\mu} \leftarrow\!\$\ \mathcal{I}_c$

$\underline{\text{Login}(c, \text{OS}, \text{CL}, \text{RP})}$
If $c > \mu$ then Return $\perp$
$(sid, st_c, st_{\text{rp}}) \leftarrow\!\$\ \mathcal{L}((st_c, \text{OS}, \text{C}$
$\gamma_{c,sid} \leftarrow \text{True}$
$q \leftarrow q + 1$
$\mathcal{T}^*[q] \leftarrow (\text{INIT}, c, sid, \text{OS}, \text{CL}, \text{R}$
Return (sid, st_c)

$\underline{\text{Action}(c, sid, \text{OS}, \text{CL}, \text{RP})}$
If $\gamma_{c,sid} = \perp$ then Return $\perp$
$(st_c, st_{\text{rp}}) \leftarrow\!\$\ \mathcal{N}((st_c, sid, \text{OS}, \text{C}$
$q \leftarrow q + 1$

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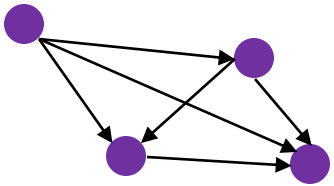

- Define reachability graph to characterize ciphertext access

Theorem: Assuming secure encryption, our scheme achieves privacy, unlinkability, and log access determined by the reachability graph

$\underline{\text{PRIV}_{\Pi}(\mathcal{D})}$
$st_{\text{rp}} \leftarrow\$ \mathcal{I}_s$; $b \leftarrow\$ \{0,1\}$
$b' \leftarrow\$ \mathcal{D}^{\mathcal{O}}(st_{\text{rp}})$
Return

$\underline{\text{UNLINK}_{\Pi}(\mathcal{D})}$
$b \leftarrow\$ \{0,1\}$
$st_{\text{rp}} \leftarrow\$ \mathcal{I}_s$
Return

$\underline{\text{LIS}_{\Pi,\text{prune}}(\mathcal{A})}$
$st_{\text{rp}} \leftarrow\$ \mathcal{I}_s$; win $\leftarrow 0$
$\mathcal{A}^{\mathcal{O}}$
Return win

$\underline{\text{InitClient}}$
$\mu \leftarrow \mu + 1$; $st_{\mu} \leftarrow\$ \mathcal{I}_c$

$\underline{\text{Login}(c, \text{OS}, \text{CL}, \text{RP})}$
If $c > \mu$ then Return $\perp$
$(sid, st_c, st_{\text{rp}}) \leftarrow\$ \mathcal{L}((st_c, \text{OS}, \text{C}$
$\gamma_{c,sid} \leftarrow$ True
$q \leftarrow q + 1$
$\mathcal{T}^*[q] \leftarrow (\text{INIT}, c, sid, \text{OS}, \text{CL}, \text{R}$
Return (sid, st_c)

$\underline{\text{Action}(c, sid, \text{OS}, \text{CL}, \text{RP})}$
If $\gamma_{c,sid} = \perp$ then Return $\perp$
$(st_c, st_{\text{rp}}) \leftarrow\$ \mathcal{N}((st_c, sid, \text{OS}, \text{C}$
$q \leftarrow q + 1$

CSAL deployment architecture challenges

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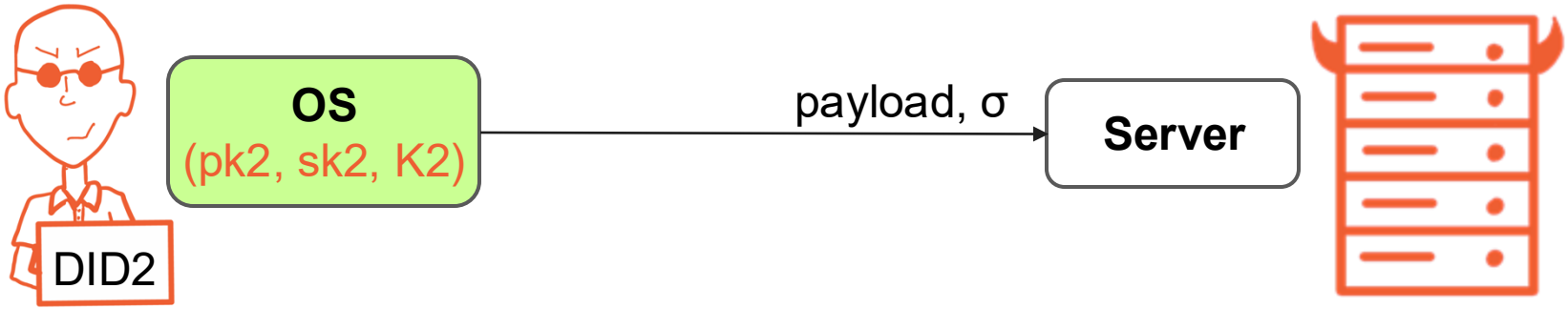

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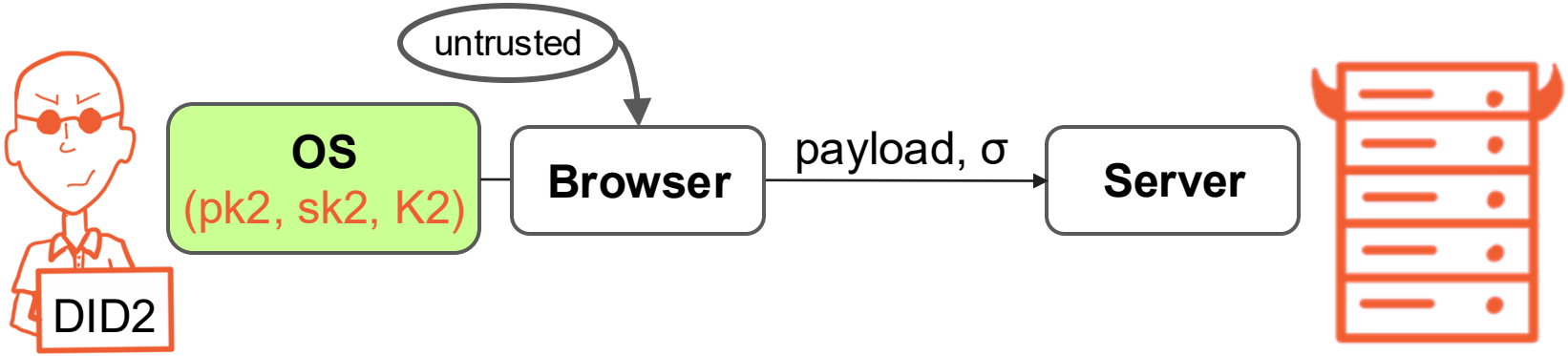

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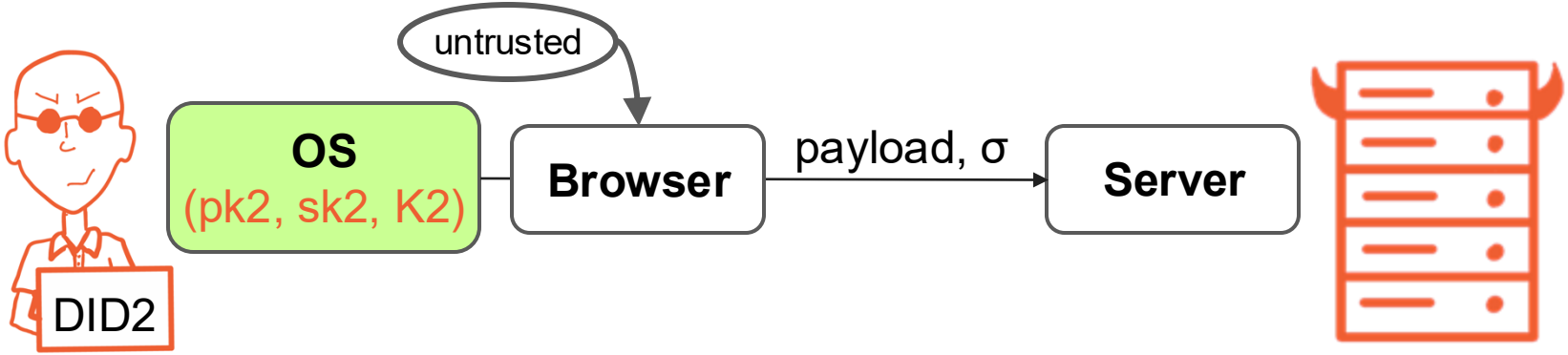
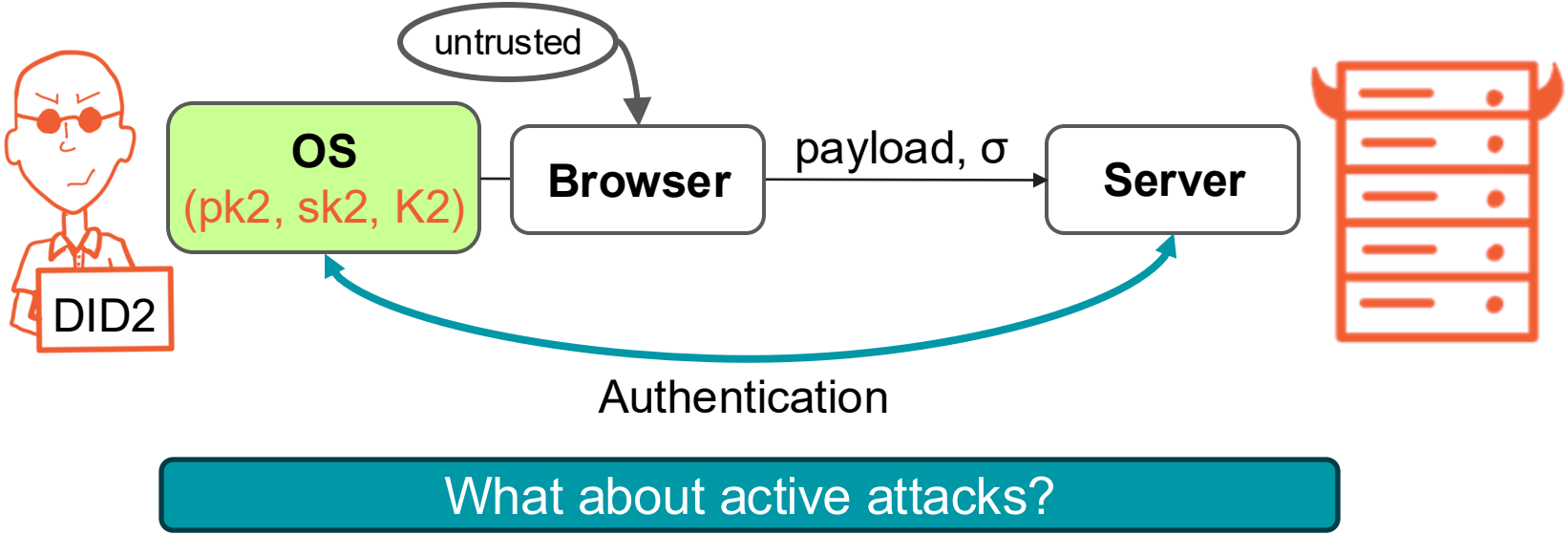


What about active attacks?

CSAL deployment architecture challenges



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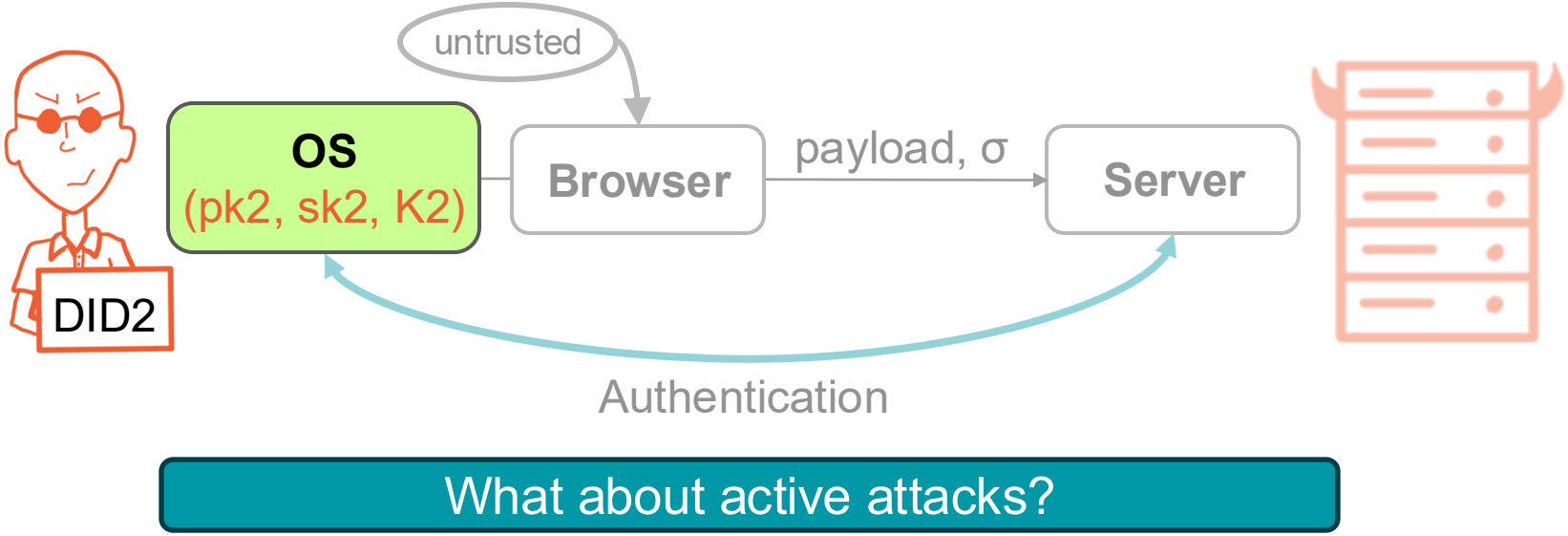

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CSAL deployment architecture: OS authentication

- Based on the **FIDO2 framework**
  - Specifications for device authentication
  - WebAuthn → Passkeys
    - API to register and authenticate users using an authenticator

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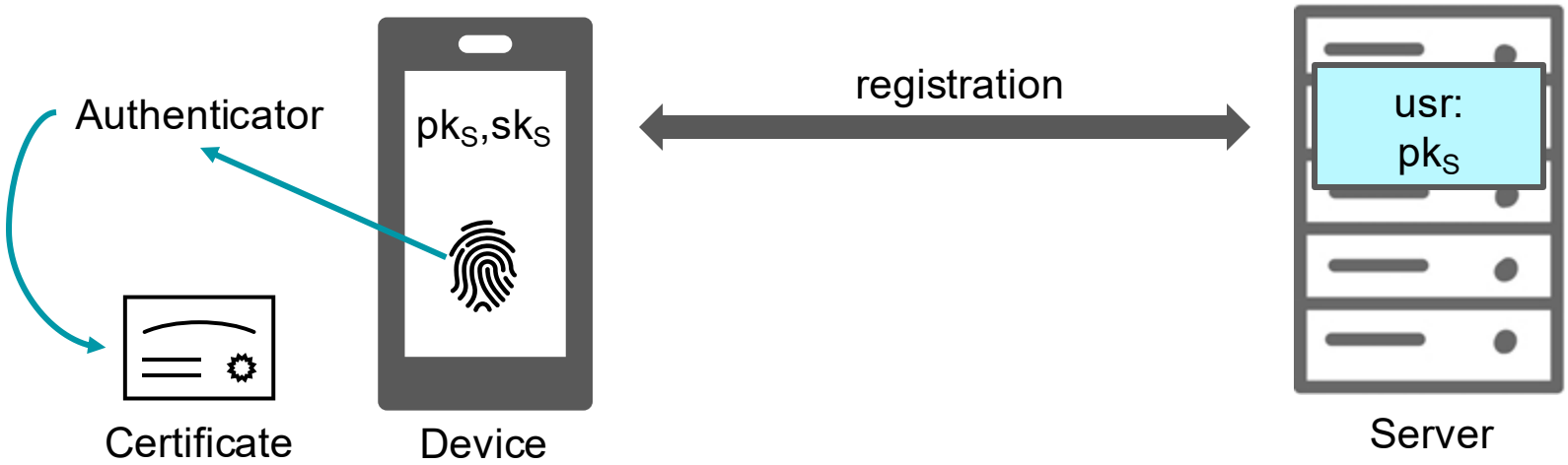

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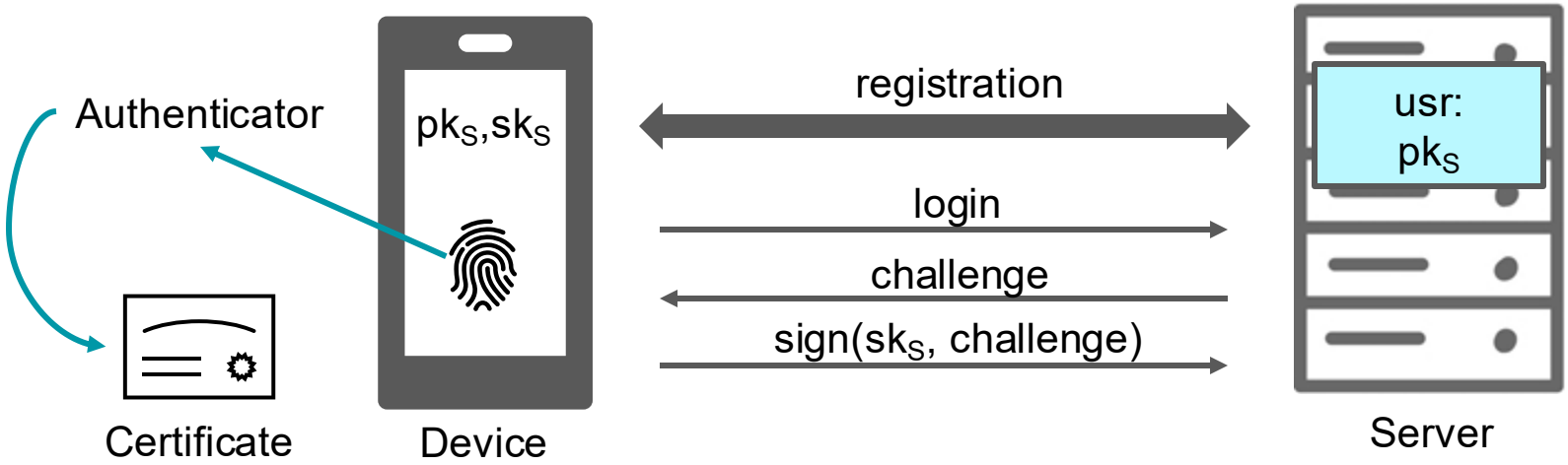

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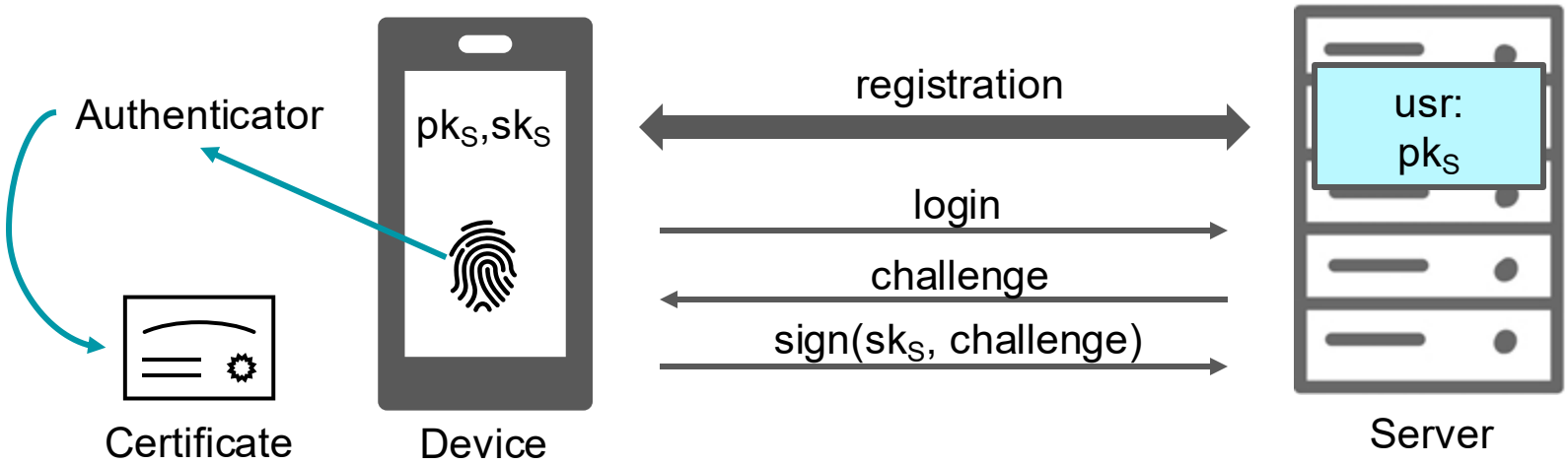
Why FIDO2?
- Collaboration with OS vendors
- Handles cryptographic keys
- Widely deployed



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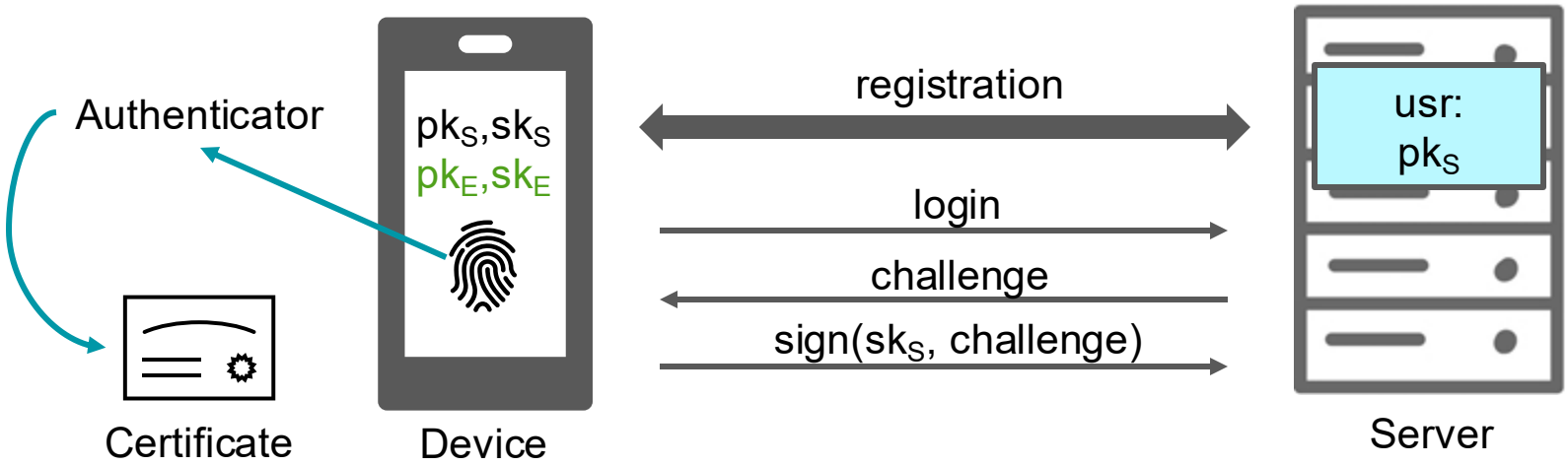

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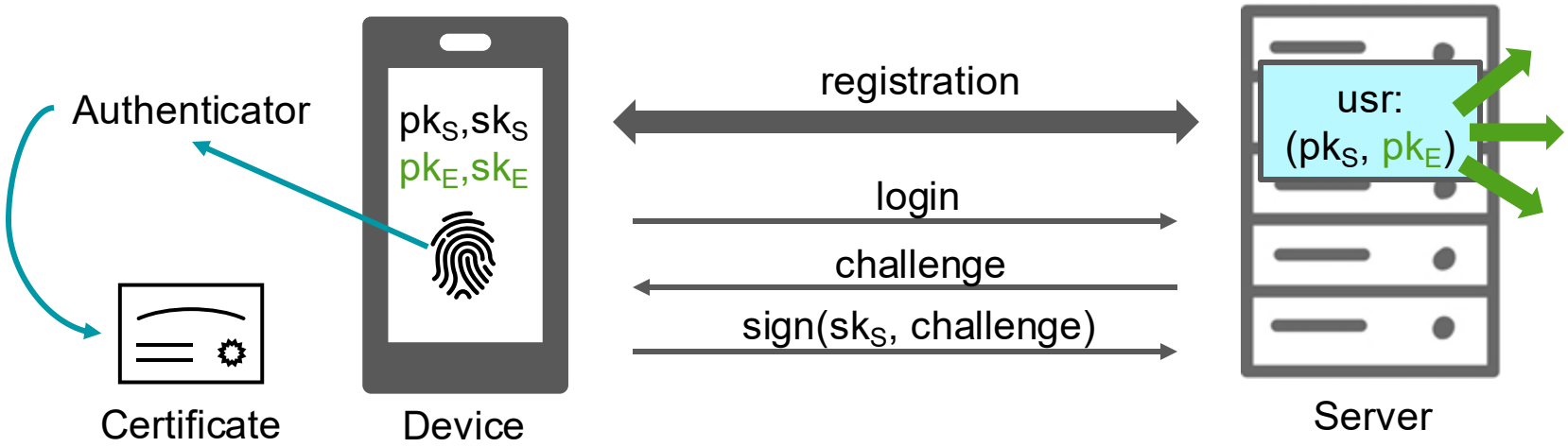

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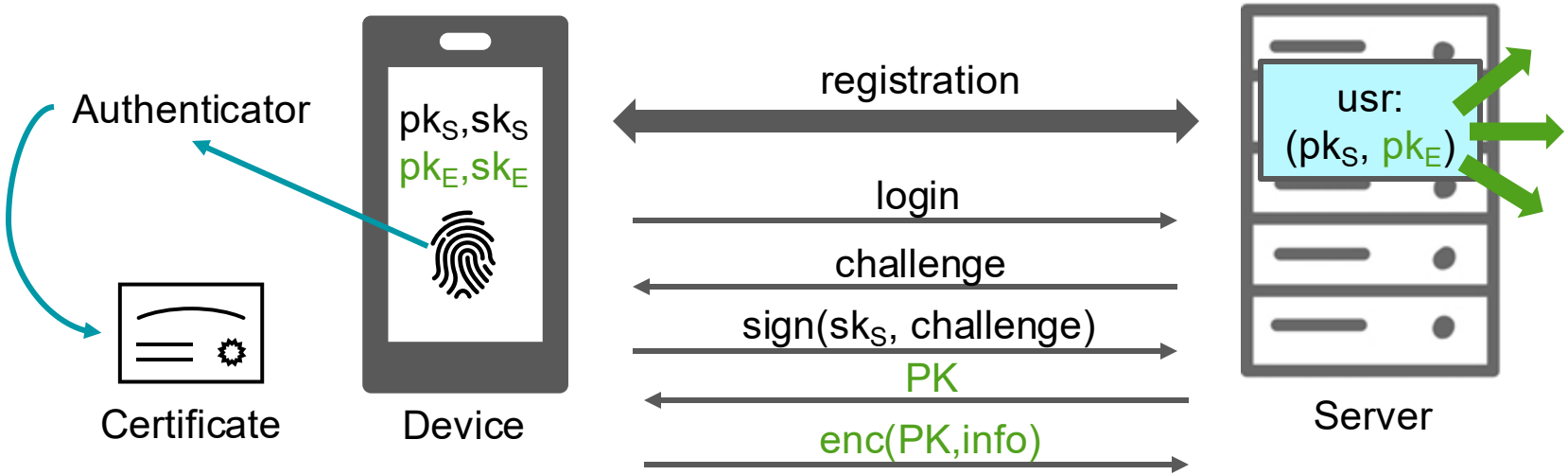

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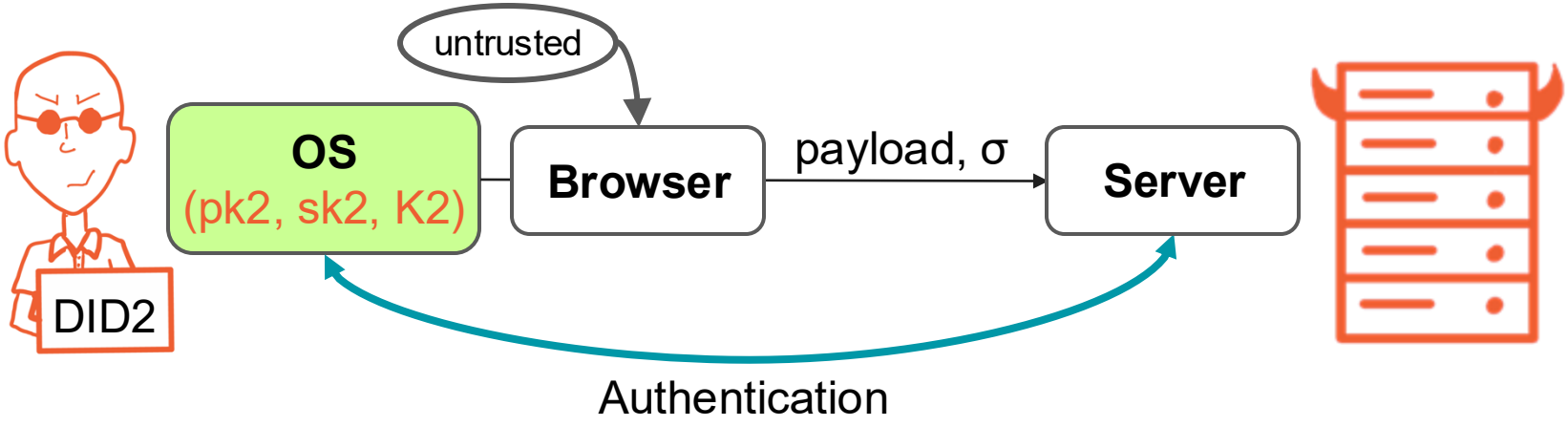

What about active attacks?

OS Authentication

FIDO2-style certificates

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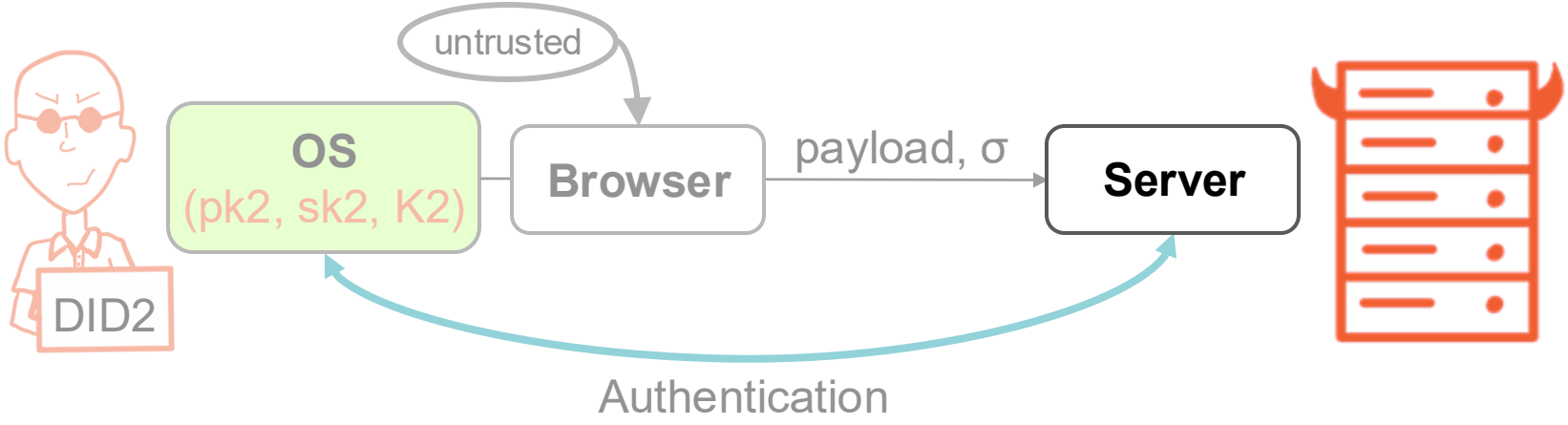

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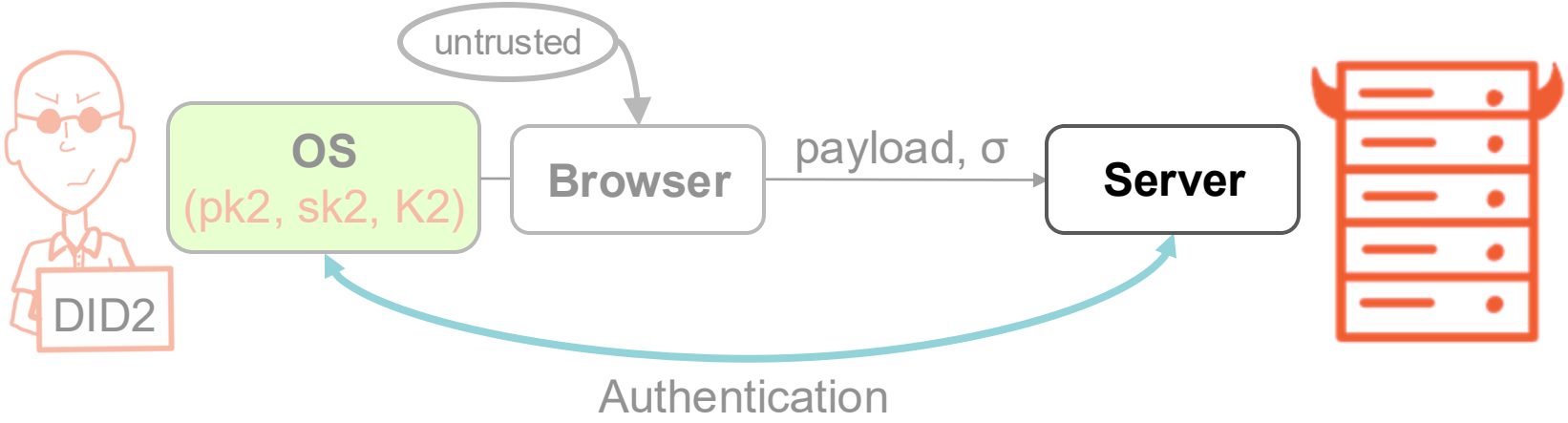

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Infrastructure similar to TLS

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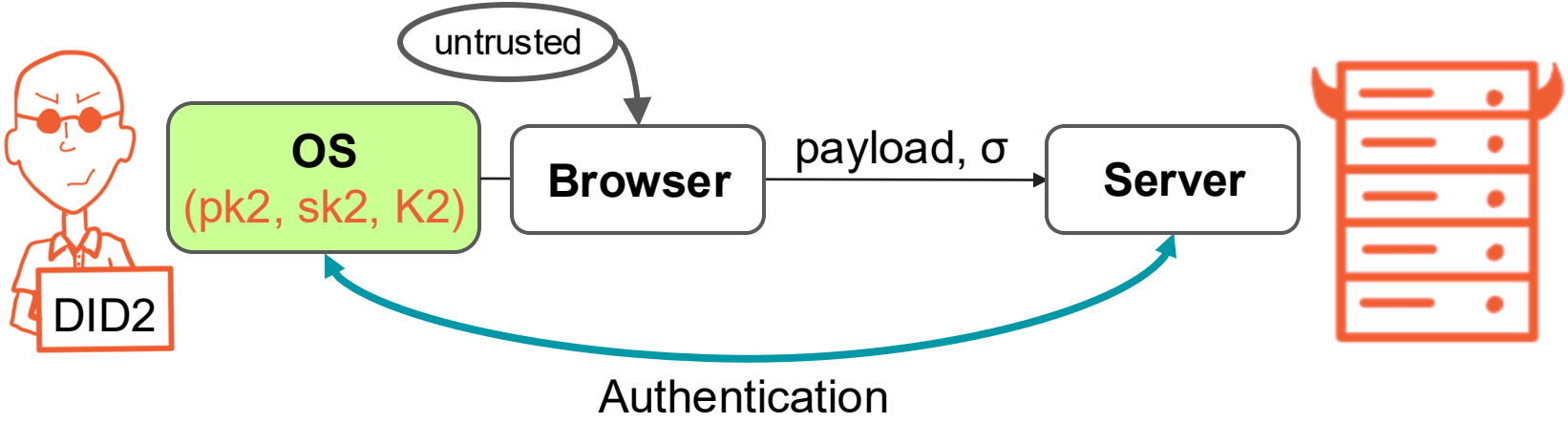

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✅ Browser MiTM

❌ Server MiTM

Proof of concept

- Prototype Python implementation of a server, client, and encryptor
  - Login:
    - Bandwidth: ~5KB per single session login
    - Latency: 146ms for single session login
  - ASI log retrieval:
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Performance-wise, the system is practical

Future work

- Deployment
  - Collaboration between OS vendors and browsers and other clients
  - Similar to FIDO2
- Formalization against malicious server
- ASIs potential risks
  - Risks of user monitoring by abuser
- ASIs UX
  - What type of information should we include in ASIs?

Encrypted Access Logging for Online Accounts: Device Attributions without Device Tracking

Takeaways:

- ASIs are important
- Trade-offs between integrity, privacy, and full access to logs
- OS signed identifiers prevent other users from tampering with logs
- Encryption ensures privacy from server
- Open challenges surrounding architecture that requires collaboration between OS vendors and platforms

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