Ownership Transfer

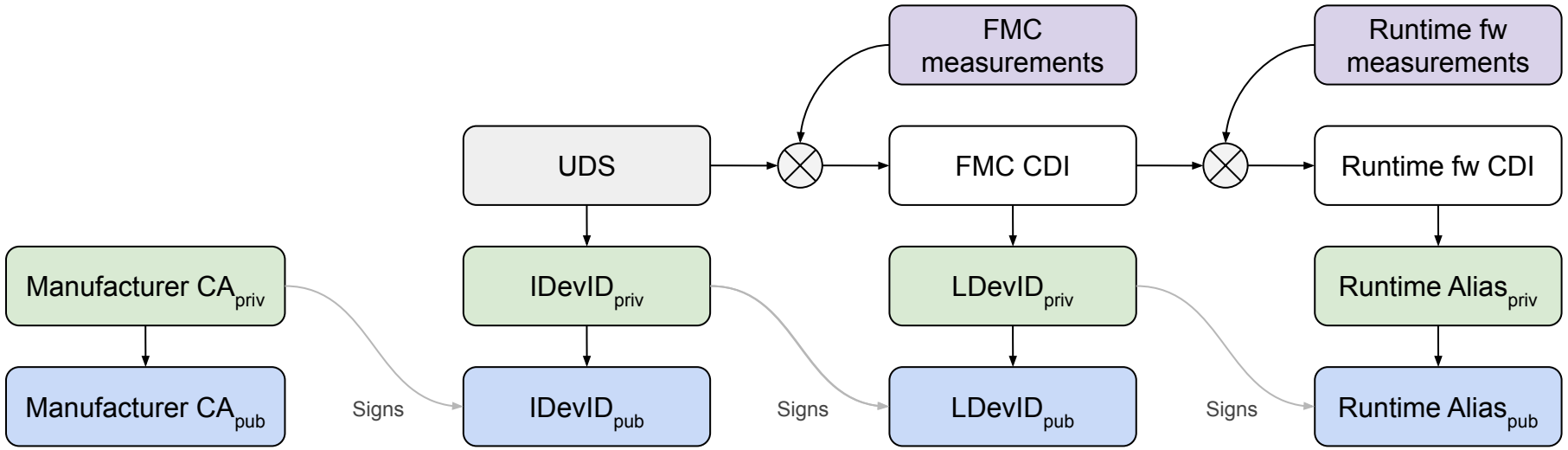
Where security meets the circular economy

Jeff Andersen (Google)

Agenda

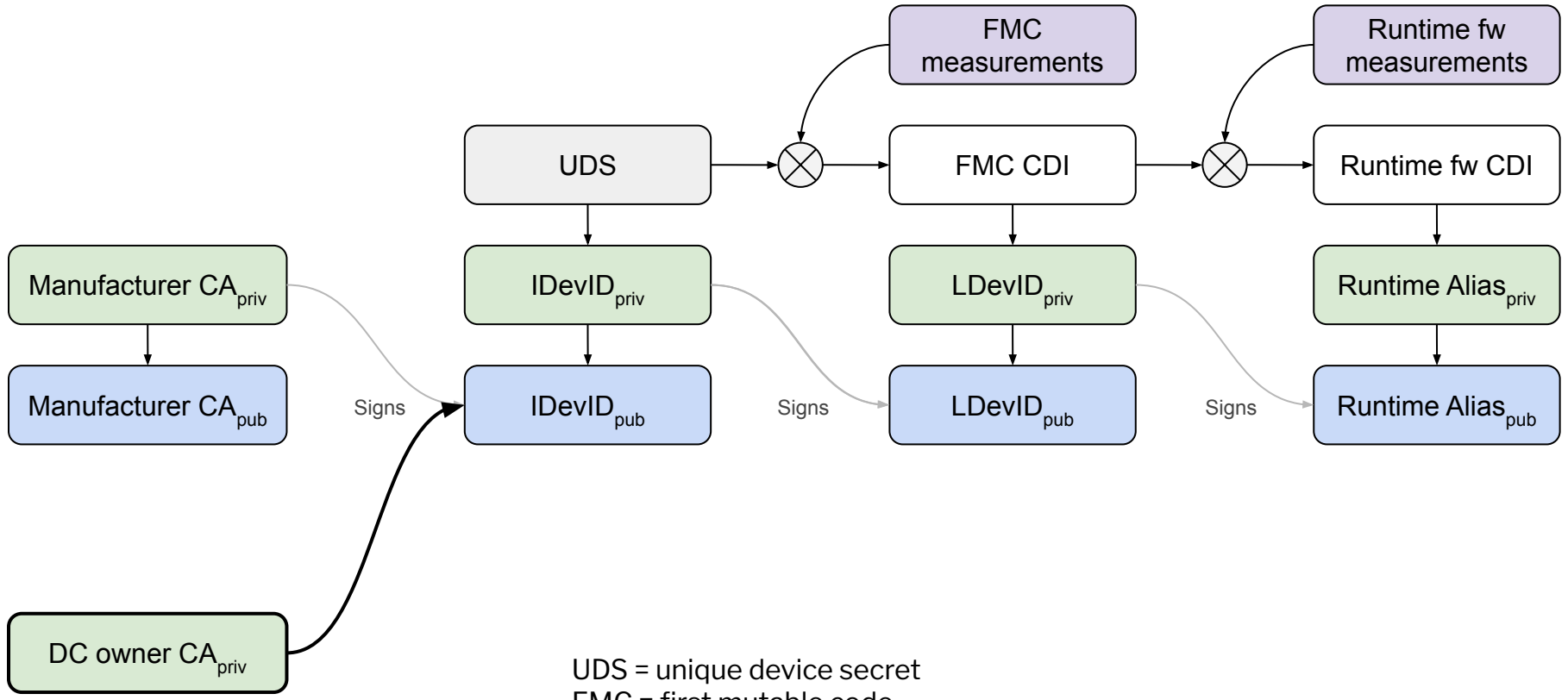
- Exploring the concept of "ownership"
- Exploring the circular economy
- Methods of ownership transfer

Ownership: Identity Endorsement



UDS = unique device secret
FMC = first mutable code

Ownership: Identity Endorsement



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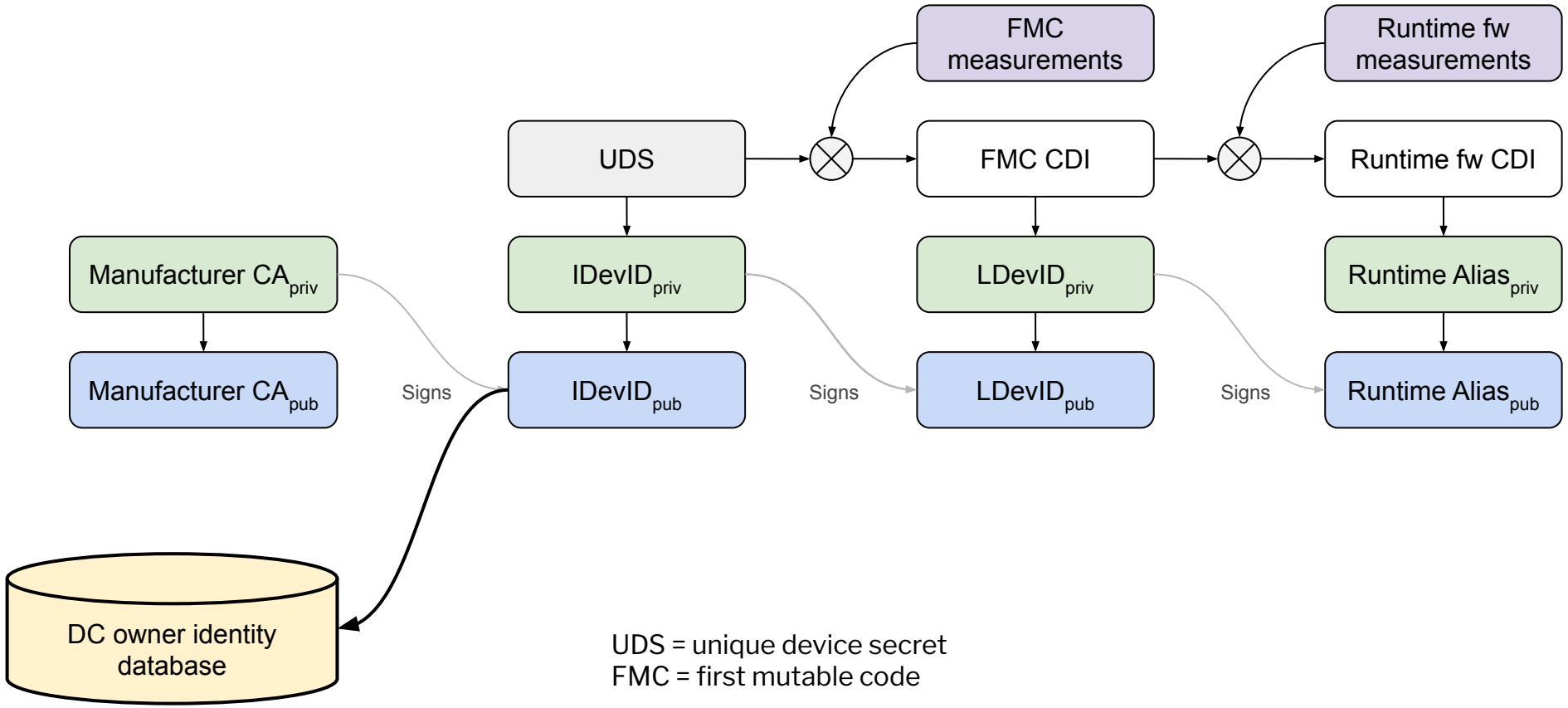
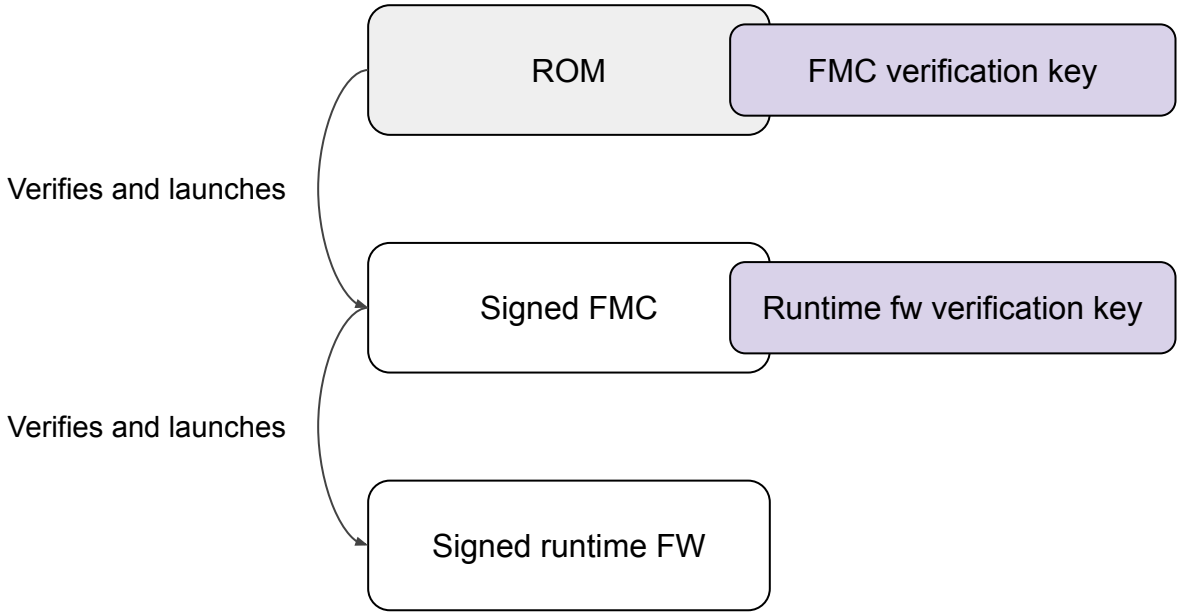


UDS = unique device secret
FMC = first mutable code

Ownership: Identity Endorsement

- Does not impact on-device state management
- Does not impact the device's behavior
  - Only affects the trustworthiness of the device's attestations

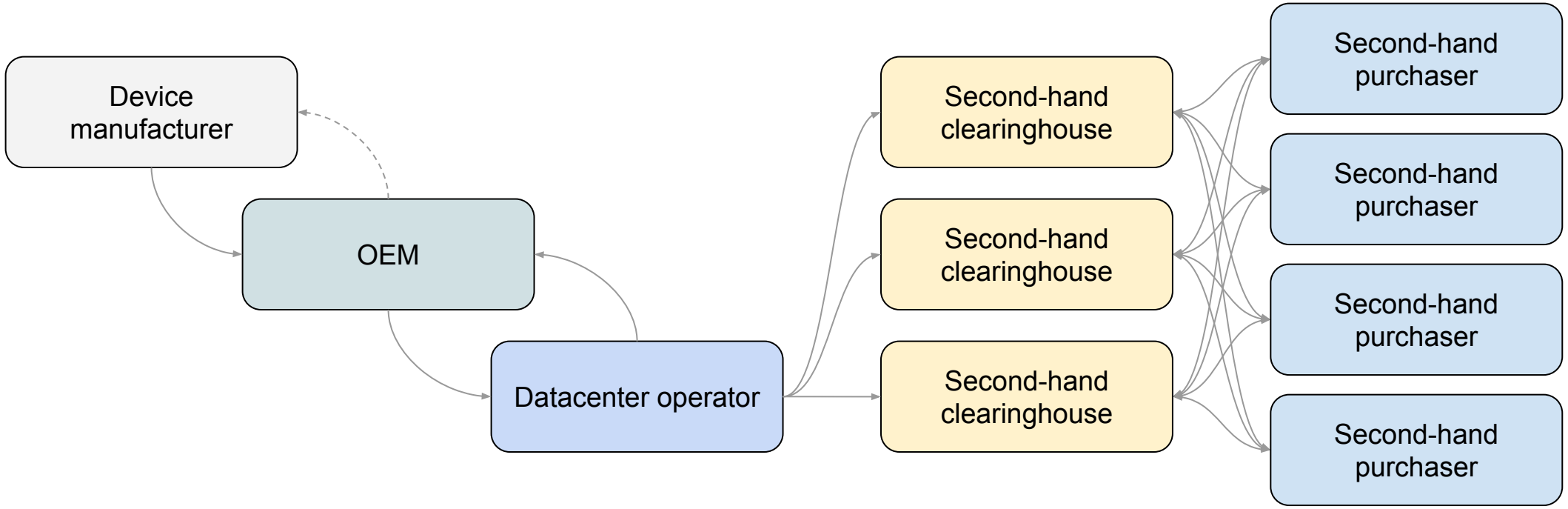
Ownership: Configuration Management



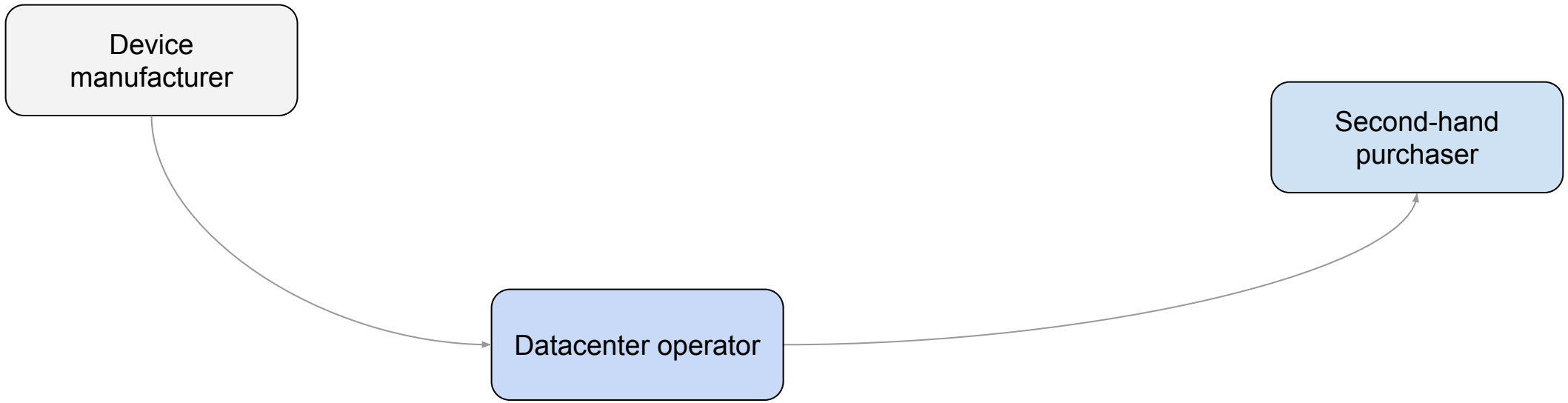
Ownership: Configuration Management

- Impacts the device's behavior
- Impacts on-device state management
- **Is the subject of ownership transfer**

Circular Economy



Circular Economy and Statefulness



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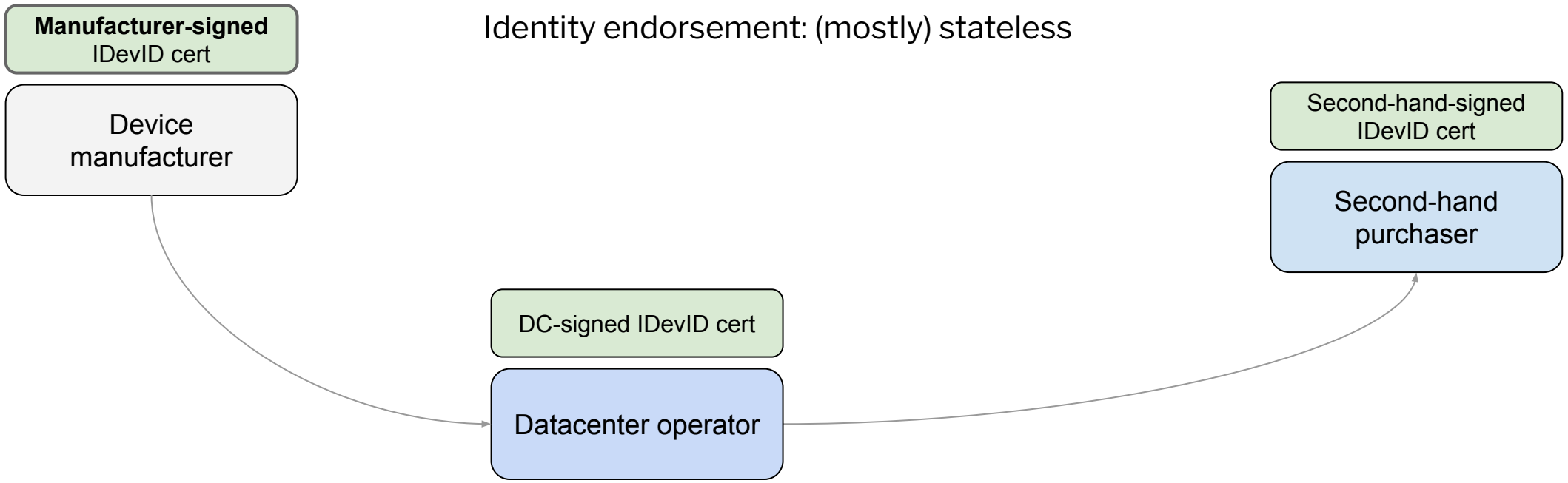

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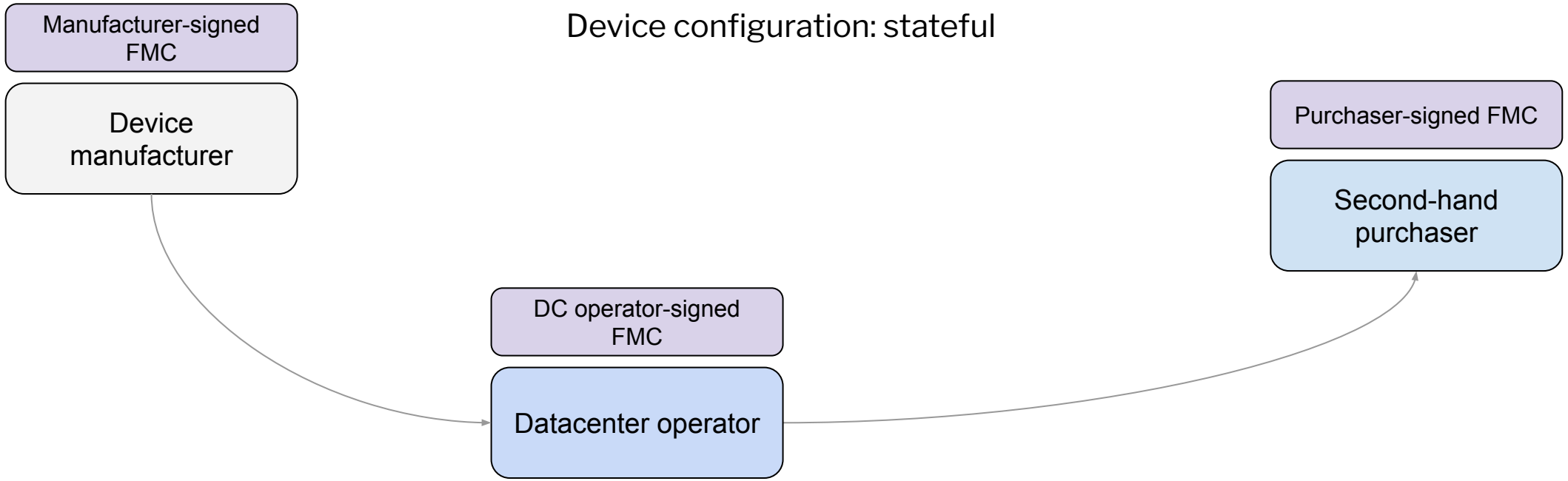
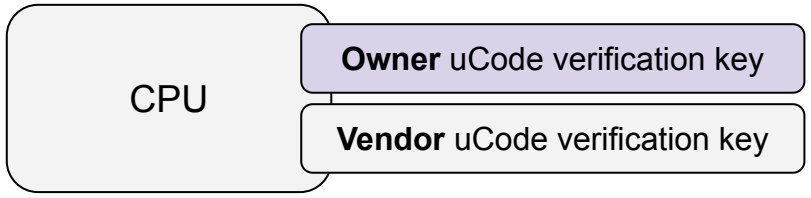


Ownership transfer definition

- **Persistent device configuration, updateable by mutually-distrusting entities**
  - At time `T=0`, device is controlled by the manufacturer
  - At time `T=1`, device is controlled by the DC operator
  - At time `T=2`, device is controlled by the second-hand purchaser
  - …
- What ownership transfer is not:
  - Device identity endorsement
  - Unauthenticated commands (ex: changing storage disk encryption keys)

Vendor control over devices

- Ownership transfer is not about giving *total* control to owners
- Vendors may wish to exert ongoing control over device behavior
  - Example: CPUs that only boot vendor-signed microcode
- The spec has an explicit carve-out for vendor control
  - Vendors might not "own" the device, but they control many of its aspects



Ownership transfer goals

Support two competing interests:

- Secure device configuration management
  - **"When the device is mine, it does what I say."**
- Healthy circular economy
  - **"I can easily sell the device to whomever I want."**

Ownership transfer on a spectrum

Fewer security assurances given to owners

Fewer circular economy roadblocks

Stronger security assurances given to owners

Greater circular-economy roadblocks

No ownership transfer

Physical-presence ownership transfer

Authenticated ownership transfer

Not all devices need ownership transfer

- Some devices only need vendor-managed configuration
  - Ex: devices that only ever run vendor firmware
- Caliptra is an example
  - An iRoT that only boots vendor-signed firmware

Physical-presence ownership transfer

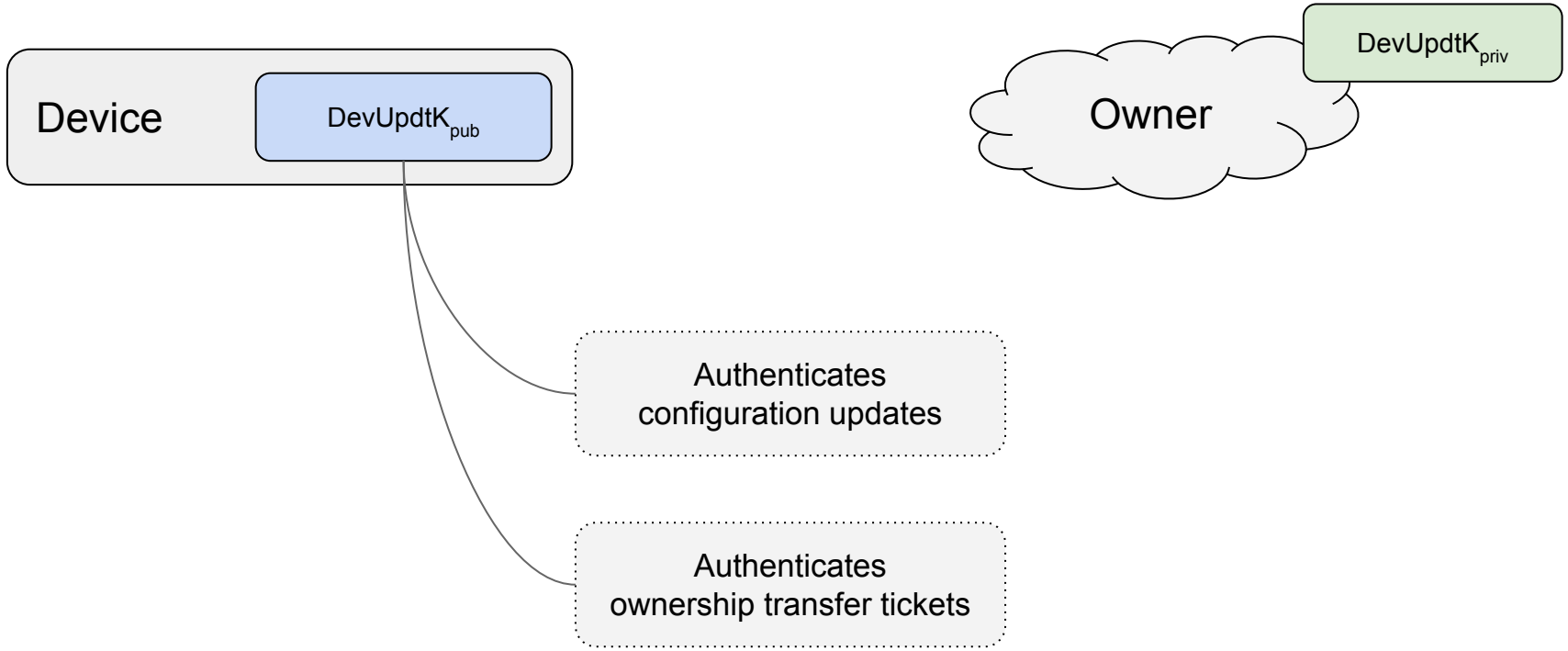
- Assert some pin to prove to the device that a prospective owner is physically present
  - Device then accepts a new configuration
- Resell is conceptually simple: buyer receives part, asserts physical presence, pushes their config
  - **Devil is in the details:** how to assert physical presence across a multitude of device models and form-factors

Authenticated ownership transfer

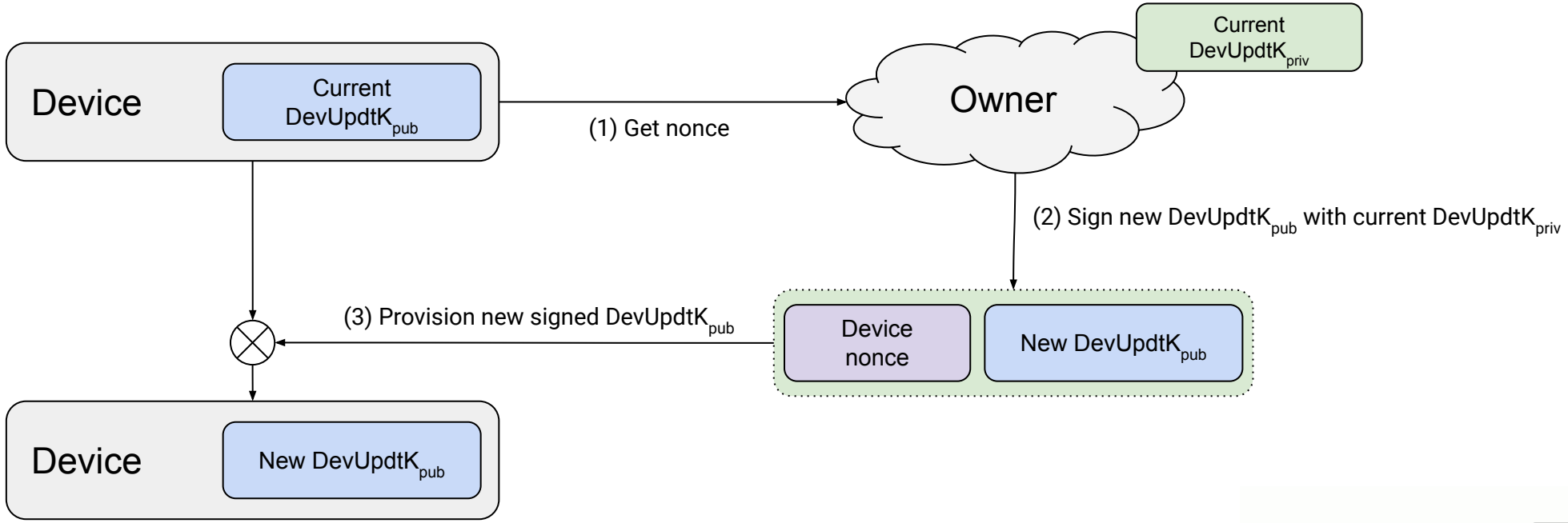
- Device configuration updated via signed tickets
  - "Configuration ownership" is conferred by way of controlling a private key
  - Physical control is not enough to assert ownership

- **Resell is much more complex**: seller and buyer must coordinate to ensure the buyer can ingest the device
  - Seller and buyer do not always know each other's identity

Terminology: DevUpdtK



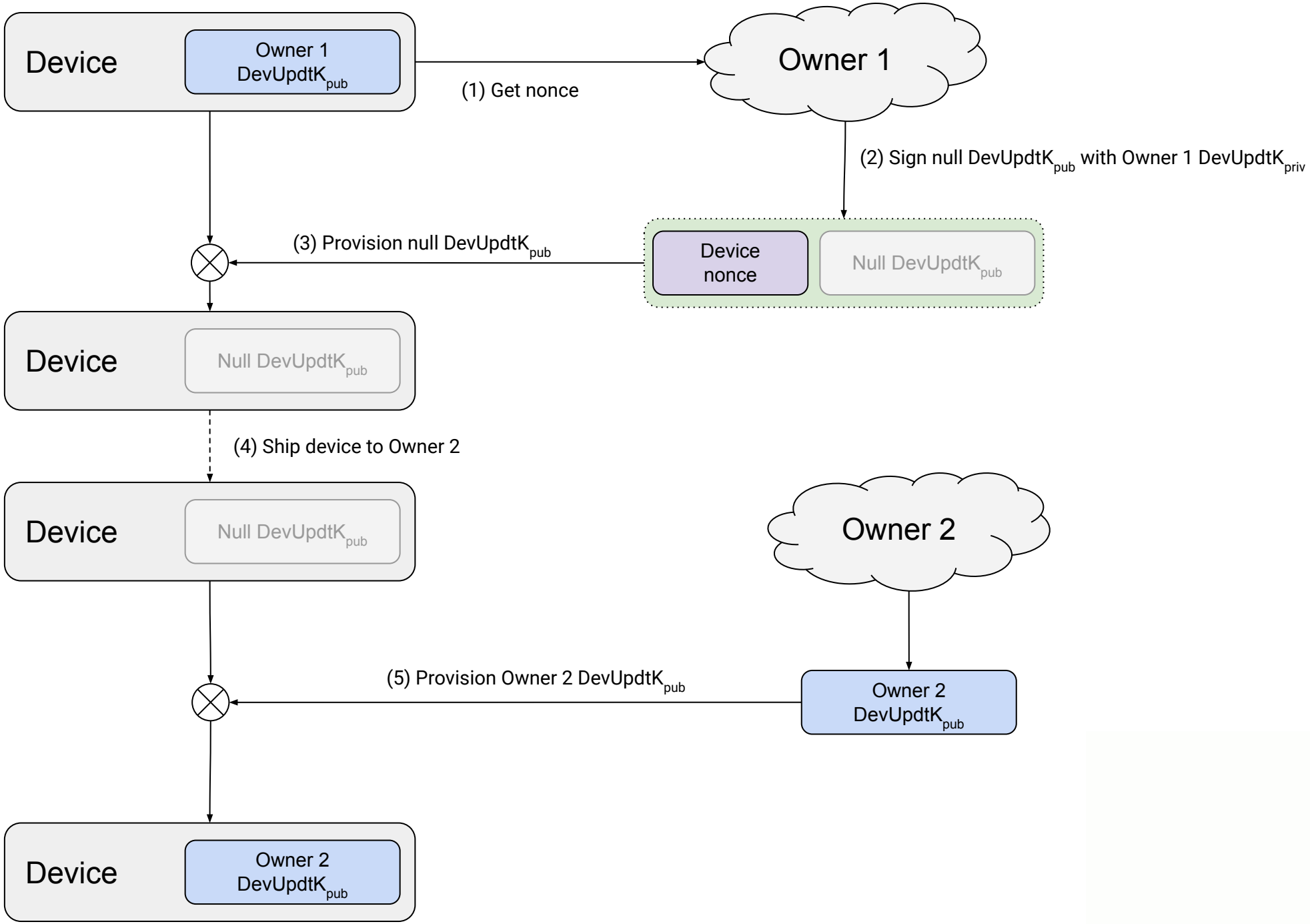
Ownership transfer via handshake

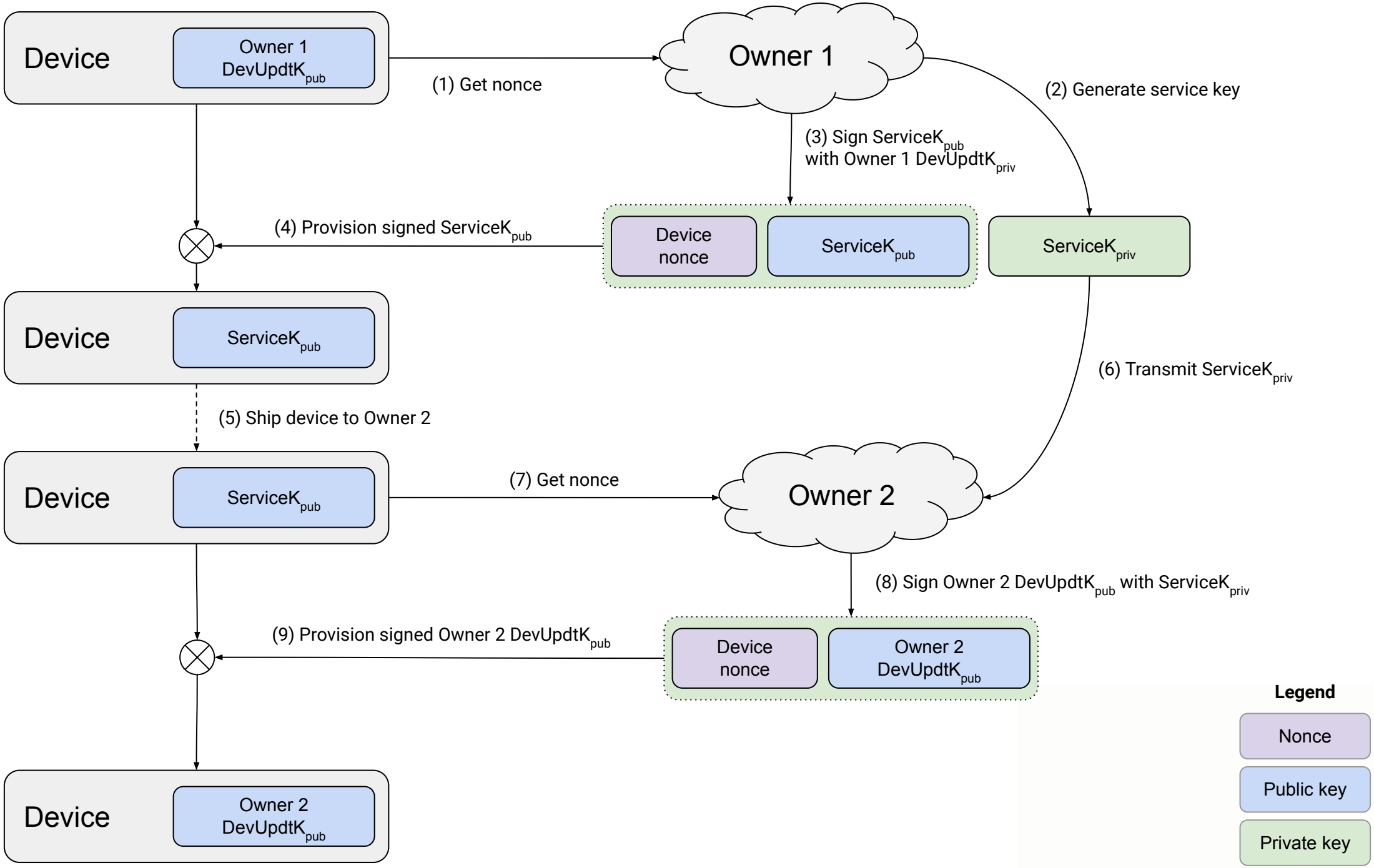


When we don't know who the next owner is

Two options:

- Transition the device into an "unowned" state before shipping
  - Provision an empty/null $DevUpdtK_{pub}$ to the device
- Use a "service key"
  - A temporary key used to ferry ownership from one entity to another


Device
Owner 1 DevUpdtK$_{pub}$
(1) Get nonce
Owner 1
(2) Sign null DevUpdtK$_{pub}$ with Owner 1 DevUpdtK$_{priv}$
(3) Provision null DevUpdtK$_{pub}$
Device nonce
Null DevUpdtK$_{pub}$
Device
Null DevUpdtK$_{pub}$
(4) Ship device to Owner 2
Device
Null DevUpdtK$_{pub}$
Owner 2
(5) Provision Owner 2 DevUpdtK$_{pub}$
Owner 2 DevUpdtK$_{pub}$
Device
Owner 2 DevUpdtK$_{pub}$
Legend
Nonce
Public key
Signature

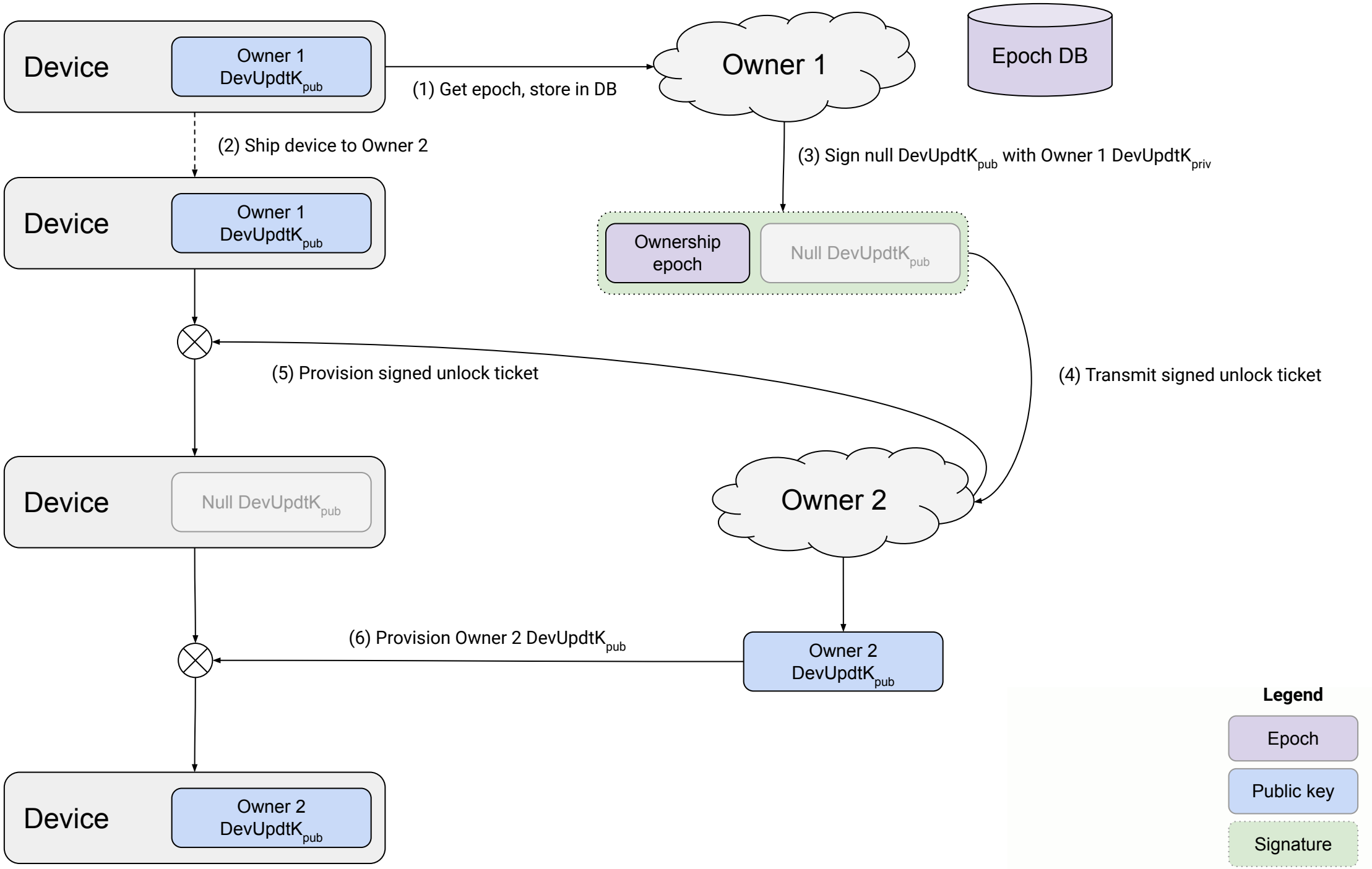

Device
Owner 1 DevUpdtK pub
(1) Get nonce
Owner 1
(2) Generate service key
(3) Sign ServiceK pub with Owner 1 DevUpdtK priv
(4) Provision signed ServiceK pub
Device nonce
ServiceK pub
ServiceK priv
Device
ServiceK pub
(5) Ship device to Owner 2
(6) Transmit ServiceK priv
Device
ServiceK pub
(7) Get nonce
Owner 2
(8) Sign Owner 2 DevUpdtK pub with ServiceK priv
(9) Provision signed Owner 2 DevUpdtK pub
Device nonce
Owner 2 DevUpdtK pub
Device
Owner 2 DevUpdtK pub
Legend
Nonce
Public key
Private key

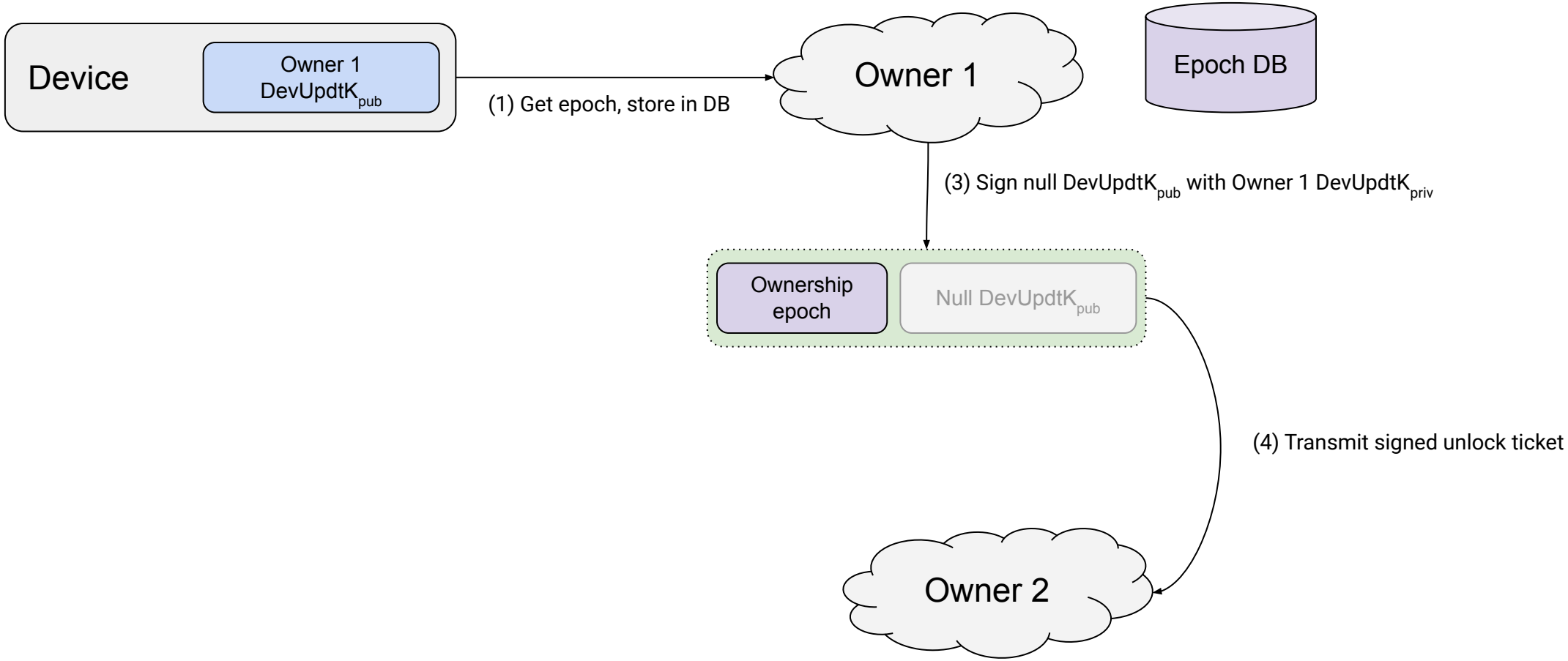
Handling RMA and Decom

- These flows all assume that ownership transfer can occur *before* the device leaves possession of the current owner
  - This assumption does not hold in two common cases
- **RMA**: Assembly is broken; techs ship it back to the vendor
  - The *device* is functional and may return to the owner, but it was unreachable when the assembly left the owner
- **Decom**: Rack is powered down, and later stripped for parts
  - Decision to decom is not made until after the rack is powered down

Approach: deferred ownership transfer

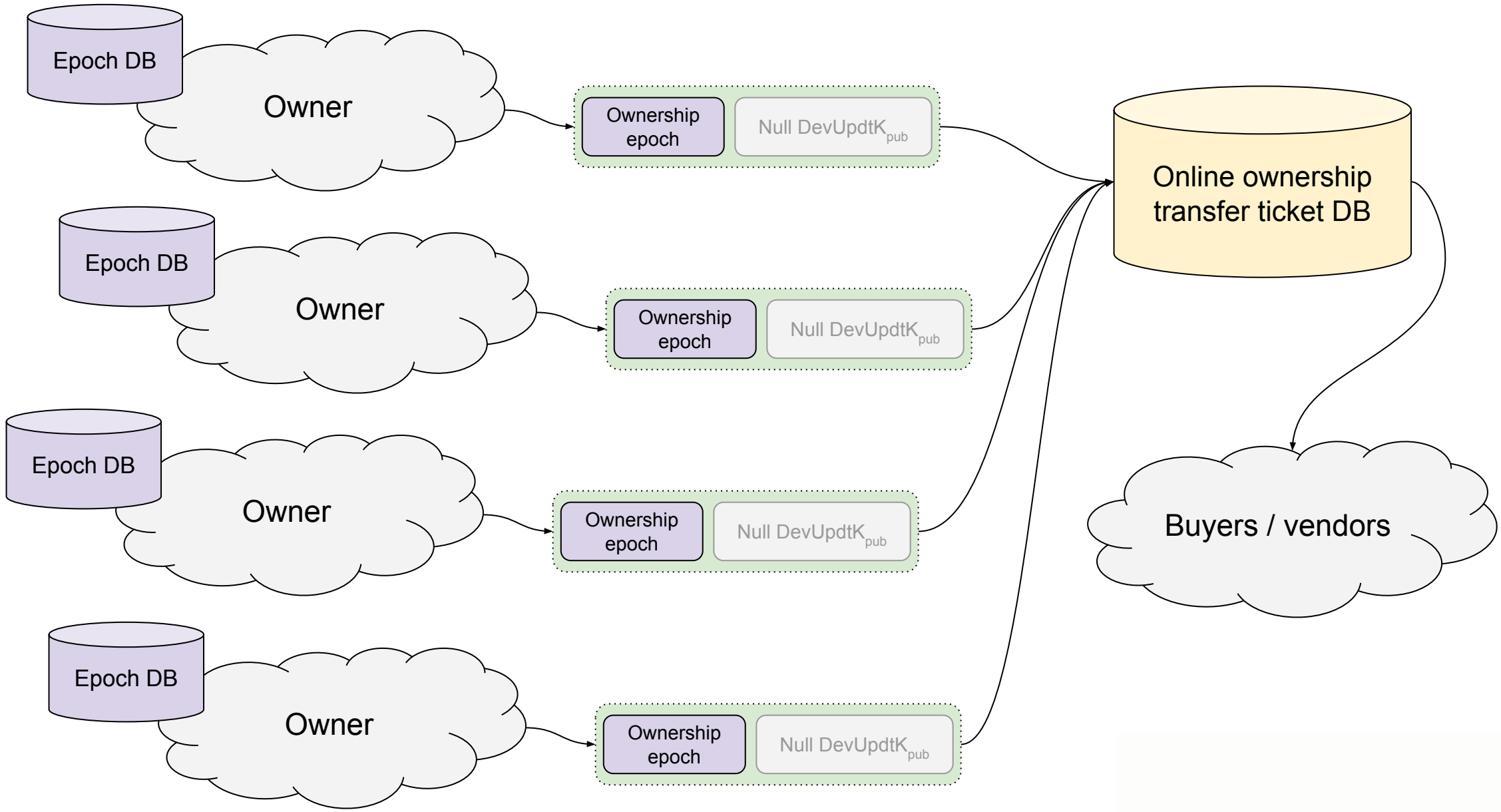
- Make ownership-transfer nonces long-lived
  - Call them **"ownership epochs"** instead
  - May be deterministic based on an internal monotonic counter
- Owners pre-fetch device ownership epochs
  - Store them in a database
- Owners can generate and sign an ownership transfer ticket *after* the device goes out the door
  - Signed tickets are transferred to the subsequent owner out-of-band


Device
Owner 1 DevUpdtK$_{pub}$
(1) Get epoch, store in DB
Owner 1
Epoch DB
(2) Ship device to Owner 2
(3) Sign null DevUpdtK$_{pub}$ with Owner 1 DevUpdtK$_{priv}$
Device
Owner 1 DevUpdtK$_{pub}$
Ownership epoch
Null DevUpdtK$_{pub}$
(5) Provision signed unlock ticket
(4) Transmit signed unlock ticket
Device
Null DevUpdtK$_{pub}$
Owner 2
(6) Provision Owner 2 DevUpdtK$_{pub}$
Owner 2 DevUpdtK$_{pub}$
Device
Owner 2 DevUpdtK$_{pub}$
Legend
Epoch
Public key
Signature

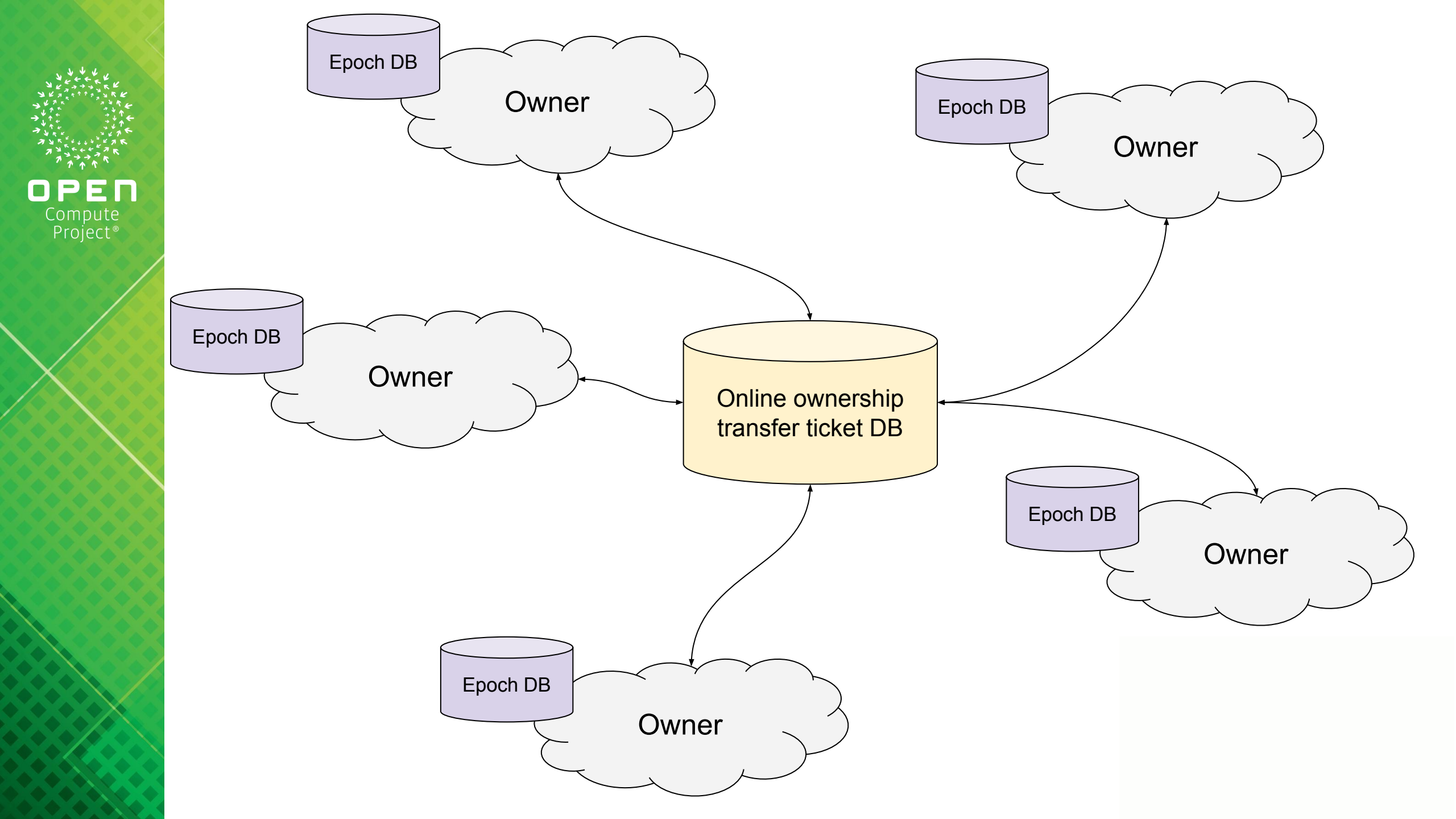


Legend

- Epoch
- Public key
- Signature



Clients pull down any tickets needed to take ownership of devices they have acquired


Epoch DB
Owner
Epoch DB
Owner
Epoch DB
Owner
Online ownership transfer ticket DB
Epoch DB
Owner
Epoch DB
Owner

Challenges with ownership transfer

- Device-side implementation questions
  - Storage substrate: fuses vs flash
  - Where and how to route a physical-presence signal
- Coordination problems - central databases are tricky
  - Database reliability
  - Owner reliability
  - Ownership transfer confidentiality

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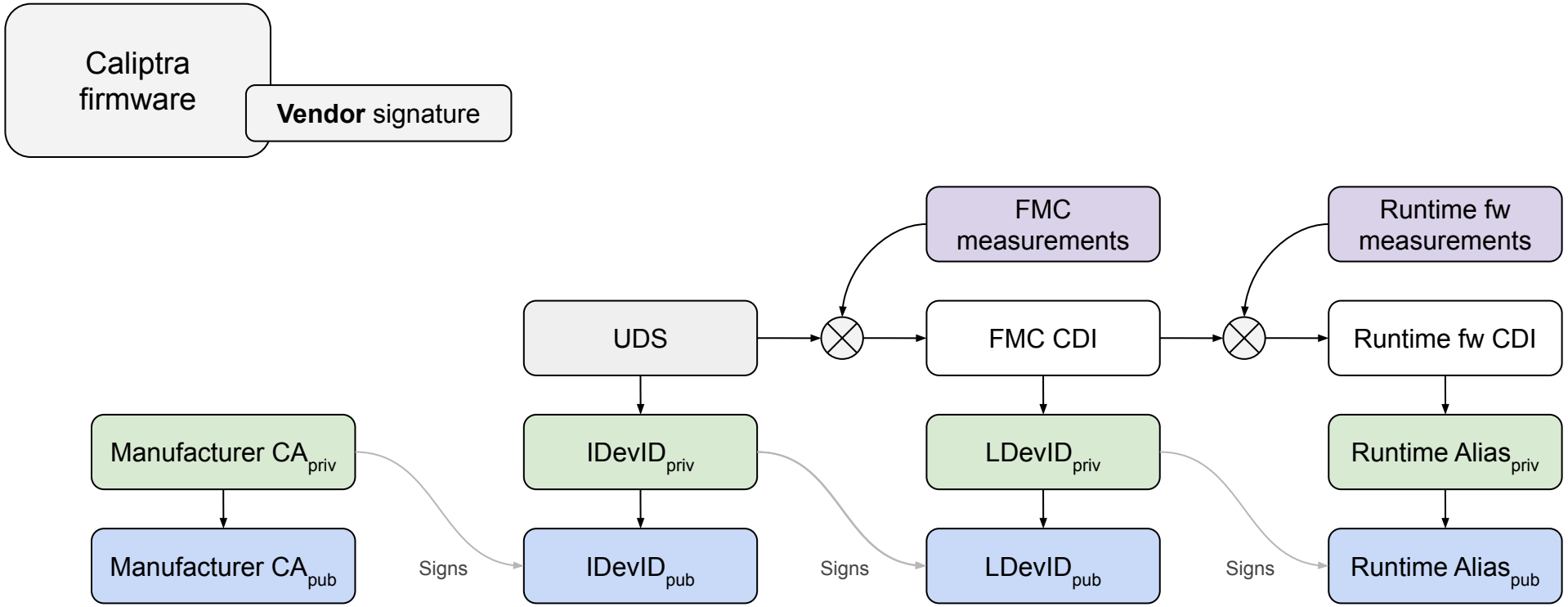
Volatile ownership authorization

Volatile ownership authorization

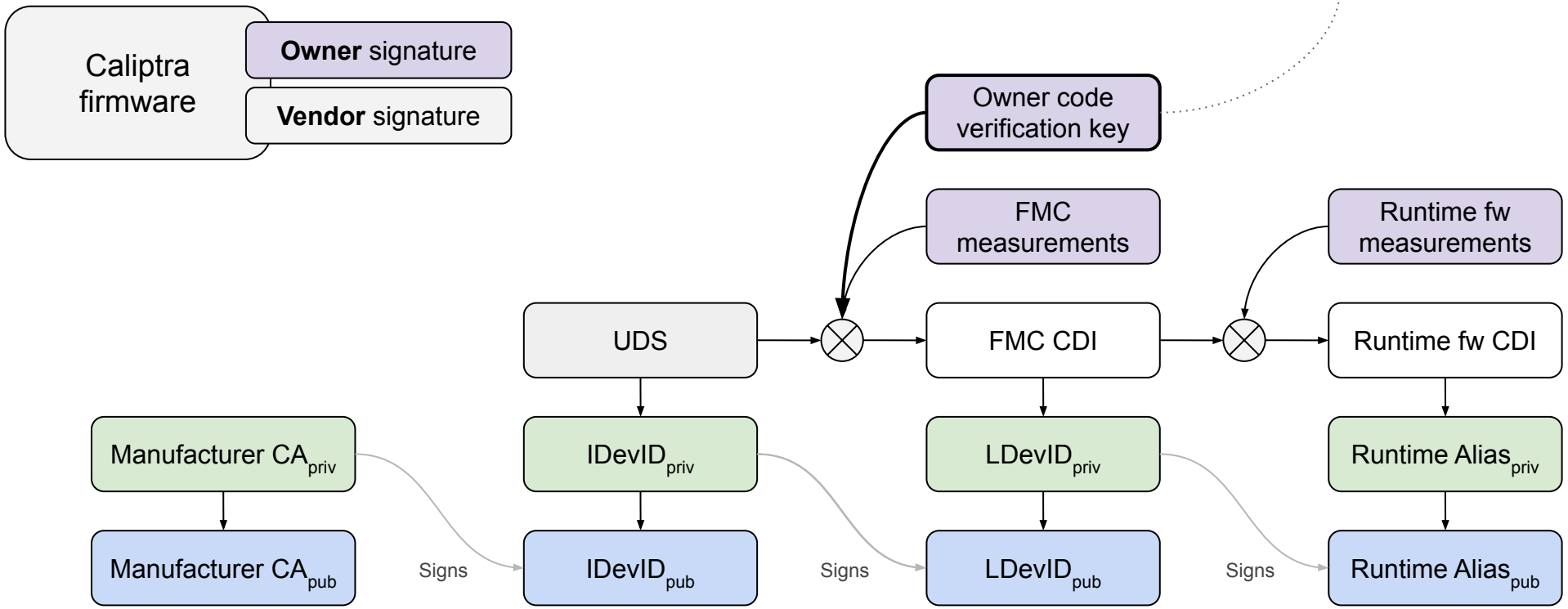
- $DevUpdtK_{pub}$ is provisioned into the device on every cold boot
  - Latched into device RAM
  - Authorizes runtime device configuration updates
- Device attests to its current $DevUpdtK_{pub}$
  - Owners can refuse to admit a misconfigured device into a serving state
- Device is "cryptographically stateless" w.r.t. config management
  - Owners can yank power and sell the device on, with no fuss

DICE in Caliptra



DICE in Caliptra

- **Co-signs Caliptra firmware**
- **Latched into Caliptra RAM on cold-boot**
- **Authorizes runtime Caliptra updates**



Current status

- High-level ownership transfer document under revision and review
  - Physical-presence ownership transfer is preferred
  - Authenticated ownership transfer is deprioritized
  - Volatile ownership authorization will be under discussion

Ownership Transfer

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Thanks!
Q&A

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