WAVE: A decentralised authorization system for IoT via blockchain smart contracts

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The problem

Authorization mechanisms tend to be centralized

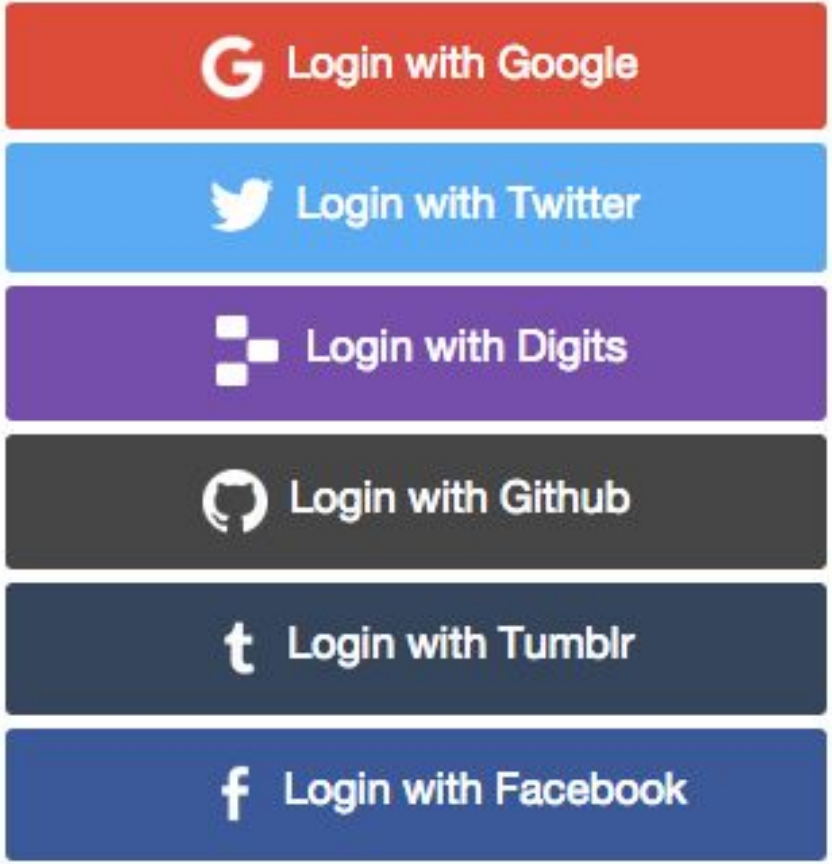
The problem: put a slightly different way

If a given user wants to trust a given device, they are generally forced to trust some other party

Examples:


AWS IoT


XMPP


Login with Google
Login with Twitter
Login with Digits
Login with Github
Login with Tumblr
Login with Facebook

This is problematic

In a global Internet of Things, who can be trusted to authorize the world?

This is problematic

In a global Internet of Things, who can be trusted to authorize the world?

Even if the company policy is “don’t be evil”, employees are fallible (or vulnerable to subpoena)

Can we build a useful system offering

Democratized authentication and authorization

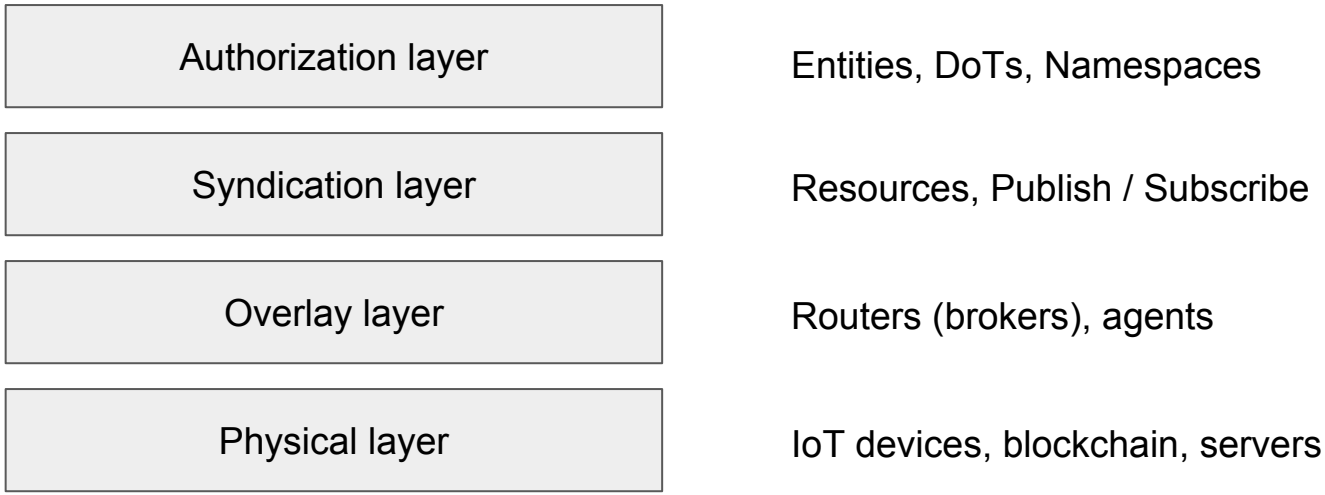
- Anyone can grant permissions
- Can do so without communicating with grantee or any authority
- Anyone can verify any permissions non-interactively

Decentralized, consistent, persistent and attack-resistant permission state

Fully authorized syndication with no trust of routers or brokers

Transparent (publicly auditable) permissions, but if desired also private

Breaking this up



Authorization layer: Entity

$<E_{sk}, E_{vk}>$

A keypair for signing and verifying

- Identified by E_{VK} e.g l0hKkvaVyRDqf_lwt93WJC_a9Zu2F3l61Au6fZtIsCU=
- Optionally identified by a globally unique, immutable alias e.g mike19
- Represents the holder of the signing key:
  - IoT device
  - Participant
  - Services

Authorization layer: Namespaces & Resources

A namespace is controlled by an entity E_{ns} and is a collection of resources:

namespace/resource_path

- All resource URIs begin with the E_{ns} of the namespace entity (or its alias)
- E_{ns} has full permissions on all resources within the namespace

alicehome/hvac/thermostat/setpoint
alicehome/security/door/islocked
caiso/pricing/zone25/electricity

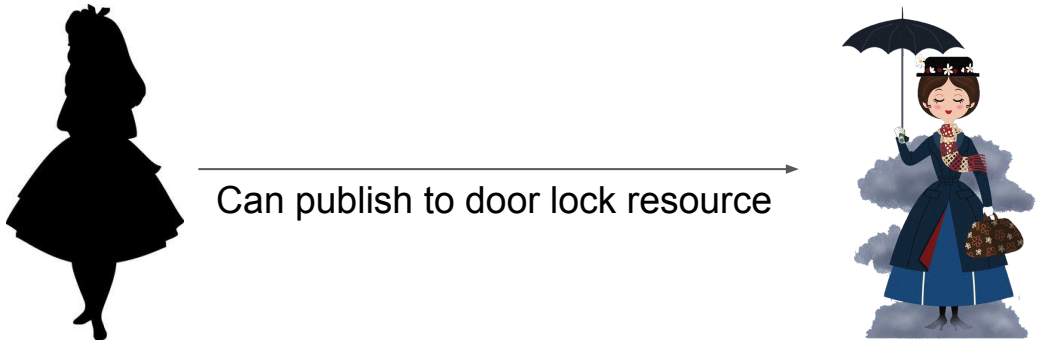
Authorization layer: Delegation of Trust

$<E_{from}, E_{to}, URI_{resource}, Permissions, Sig_{Efrom}>$

For other entities to obtain permissions on a resource, they must receive them via a *delegation of trust (DoT)*

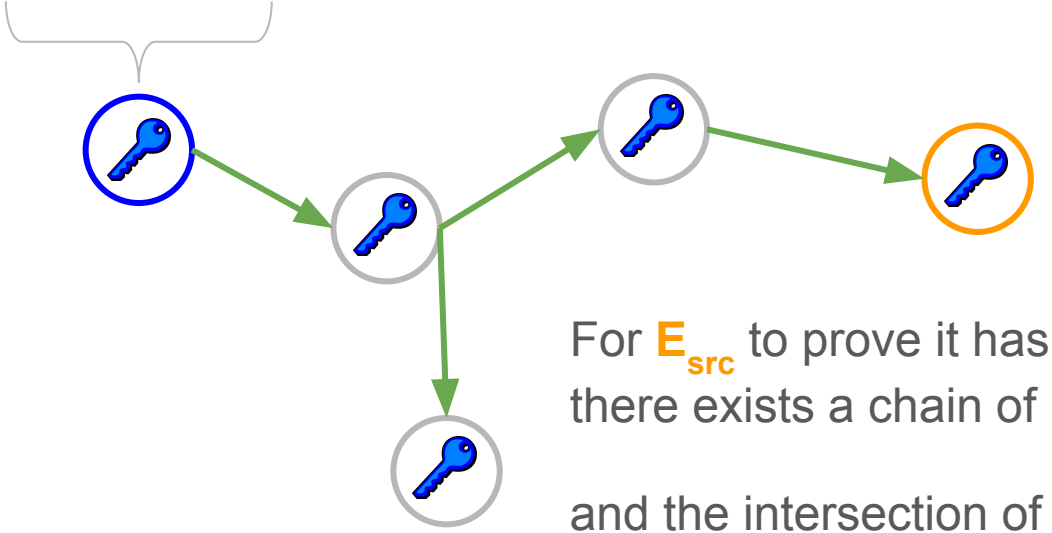
A DoT is *useful* if the granter E_{from} itself has the permissions.

This object is public and discoverable (more on that later)



Authorization layer: DoT graph

namespace/**resource path/...**



For E_{src} to prove it has **P** on a **URI**, it is sufficient to show there exists a chain of DoTs, end to end, from E_{NS} to E_{SRC}

and the intersection of the permissions granted by DoTs on this chain is greater than or equal to **P**

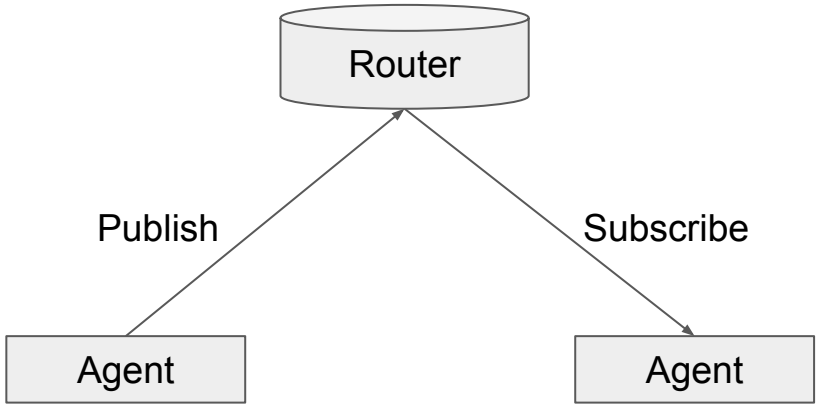
Syndication tier

- An entity can **subscribe** to a resource
- It will receive all messages **published** to that resource
- Same pattern as other pub/sub used in the IoT space

Syndication tier: messages

- A message consists of:
  - A Resource URI
  - The payload to publish to the URI
  - A chain of DoTs proving the message sender is authorized
  - A signature by the sender verifying the message has not been tampered or forged (authentication)

Overlay tier: Routers and Agents



Agent: acts on behalf of an Entity

- Builds proofs for entity
- Encodes and signs messages
- Validates incoming messages
- Participates in block chain

Router: routes messages for a namespace

- Verifies proofs
- Verifies messages
- Forwards published messages to subscribers
- Participates in block chain

So far, what do we have?

- A way of implementing authorization and syndication at a high level
- Many properties are closely linked with how the objects making up the DOT graph are disseminated and stored

- Consistency: everyone sees the same global view
- Persistence (revocations are not forgotten)
- Attack resistance: spamming etc

Many ways this could be done

- Centralized
- DHT
- Sychnronizing Key Servers (e.g GPG)

These struggle with:

- Guaranteed persistence and dissemination of revocation
- Operating without trusting the “core”

How to solve this without an authority?

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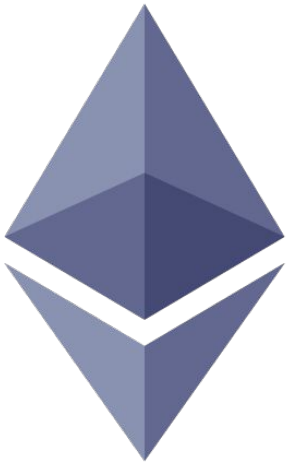


ethereum

Four contracts

WAVE object inspection:

Validate signatures
Decode packed objects

Precompiled for speed

Registry:

Store E_{vk} + metadata
Store DoT
Index objects for access

Affinity:

Store E_{NS} -> E_{DR} map
Store E_{DR} -> IP address

Like DNS but no central authority

Aliases:

Store E_{vk} <-> E_{alias} mappings

Like DNS but immutable

This solves ALMOST all the problems

Except privacy: permissions grant access to **resources**

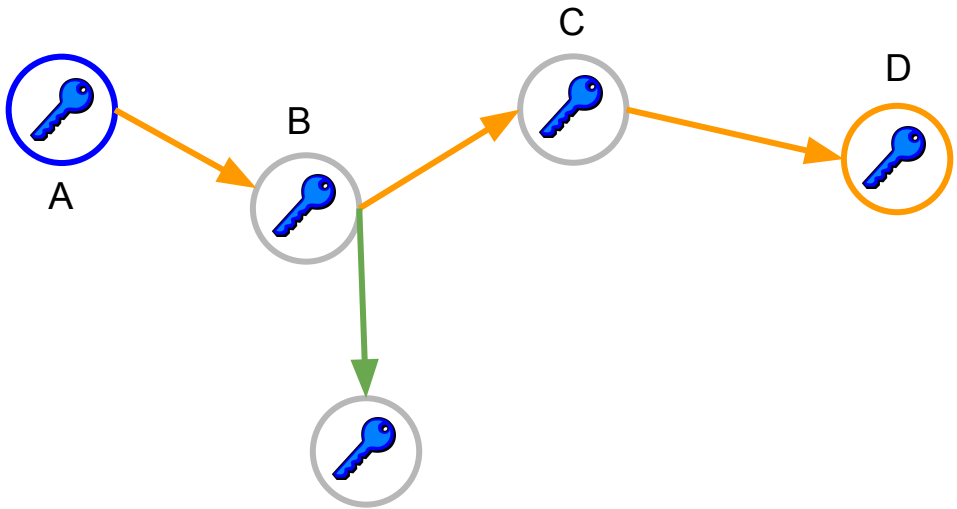
Resource URIs contain potentially sensitive information

<alice, bob, /gndfloor/lock/**samsunglock**/openstate, sub>

<ed, phil, /**17mlk**/r&d/**project_infinity**/grav_feeds, pub>

Protected DoTs

DoTs contain URI patterns which identify resources and therefore devices, services, organizational structure etc. How can we hide this?



Much harder problem that you would initially suspect

Pfft that can’t be that hard, just use:

- Encrypted session:
  Nope, granter and grantee don’t communicate
- Asymmetric crypto, just encrypt under the recipient public key
  Nope, only lets recipient see **your** DoT, not the ones leading up to it
- Ok but also include copies of the OTHER dots they need
  Nope, DoTs granted out of order, those may not even exist when you grant
- They can contact a service that gives them the DoTs
  Yes, but not without compromising on everything we stated was important
- It’s not possible
  I agreed with you until recently

Identity based encryption primer

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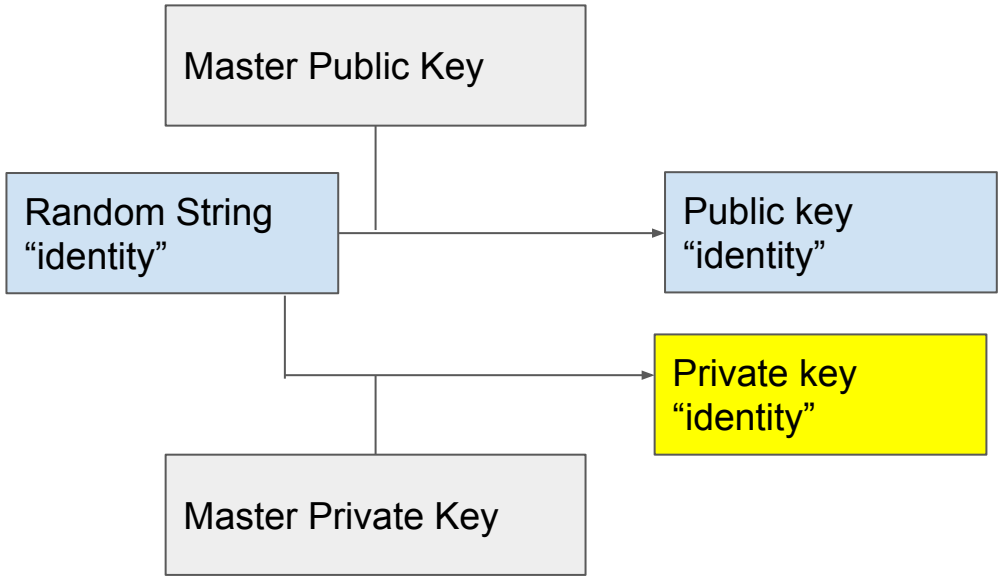
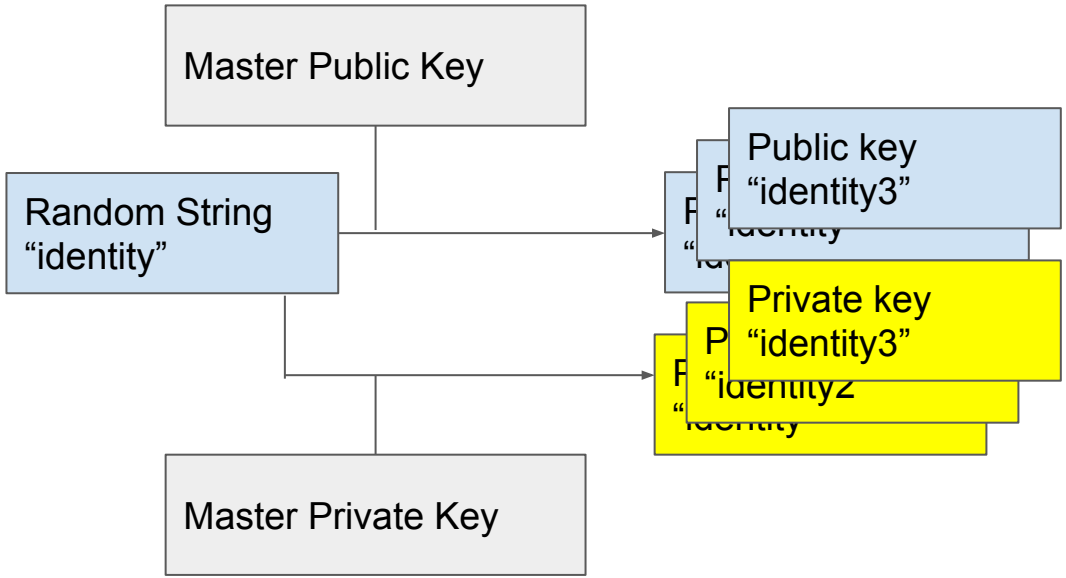
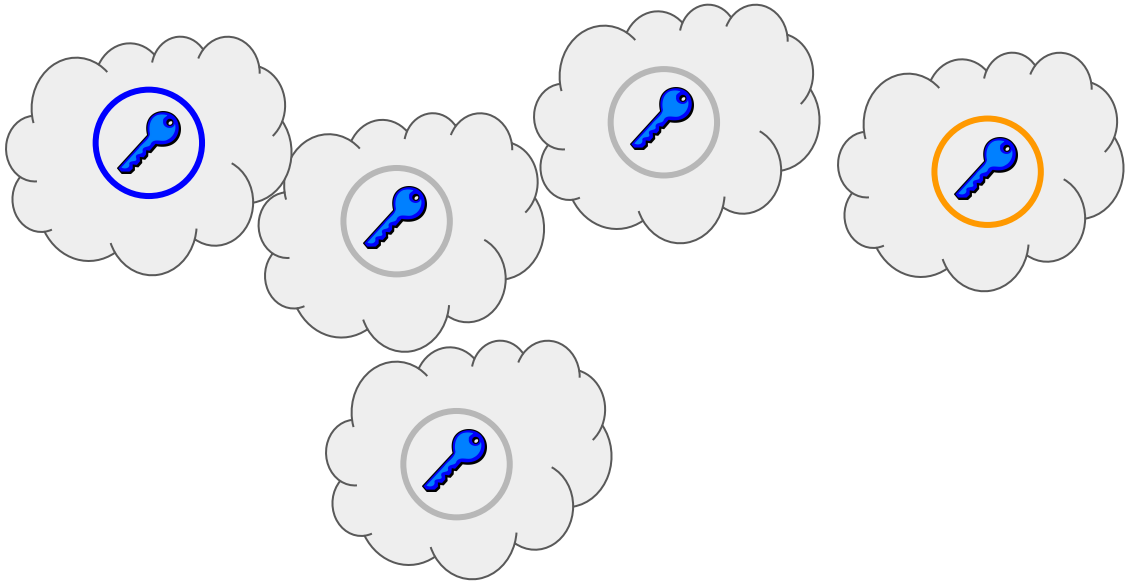


Identity based encryption primer

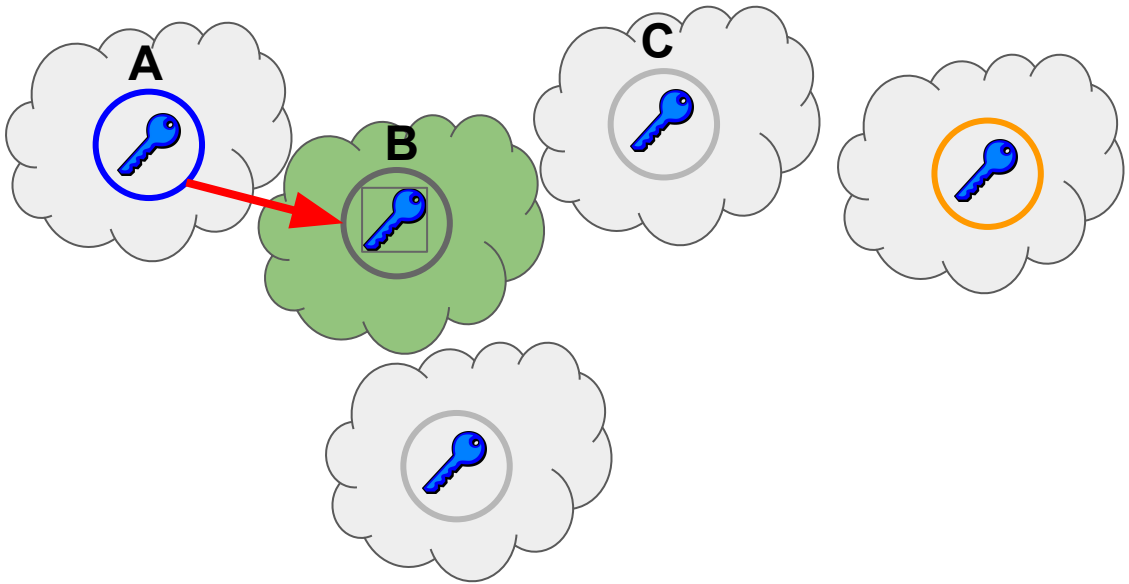


NO WAY TO GET FROM ONE PRIVATE KEY TO ANOTHER

Protected DoTs

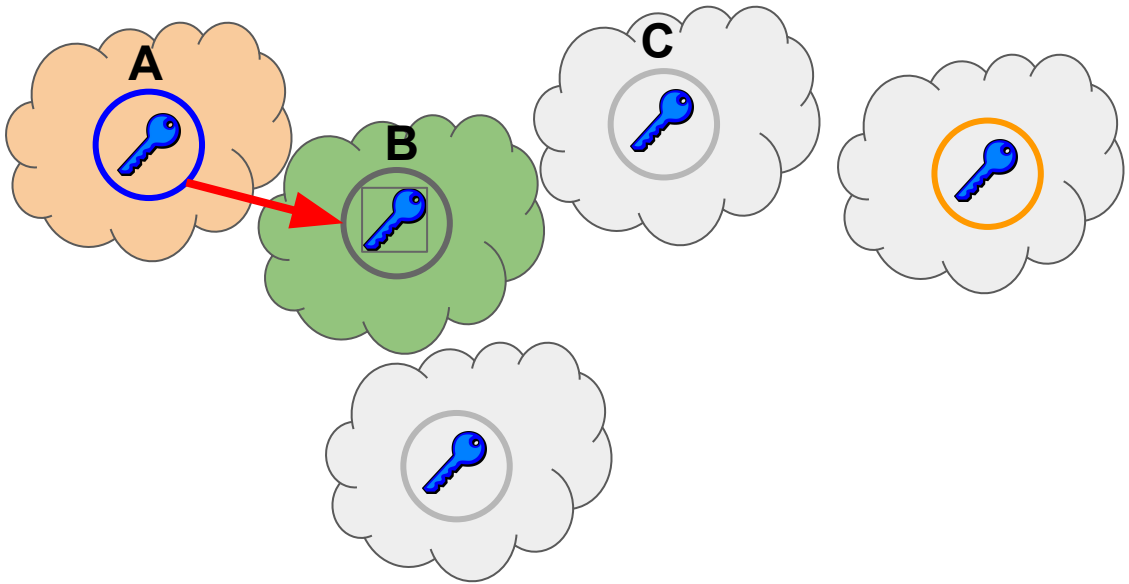


Protected DoTs



Encrypt **this DoT** in the **recipient IBE system** using the **namespace and permissions** as the “identity”

Protected DoTs

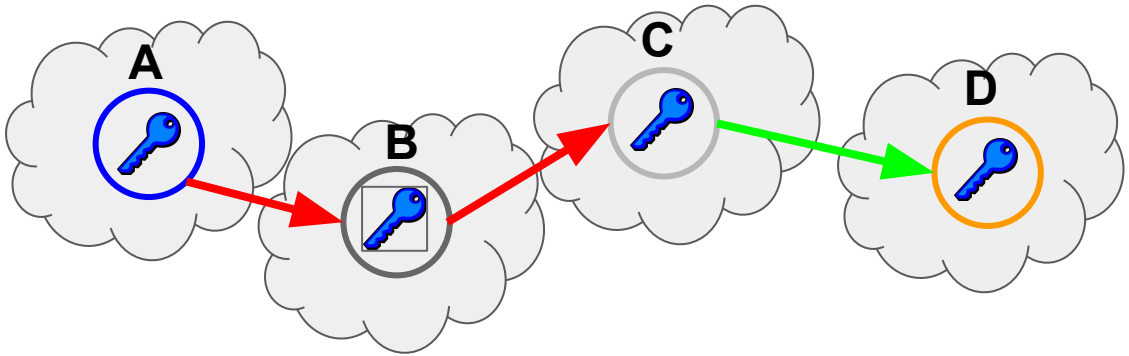


Encrypt **this DoT** in the **recipient IBE system** using the **namespace and permissions** as the “identity” but also include the PRIVATE KEY in the **source IBE system** generated with the SAME identity

Wait, the *private* key?

Yes. The private key. Just watch

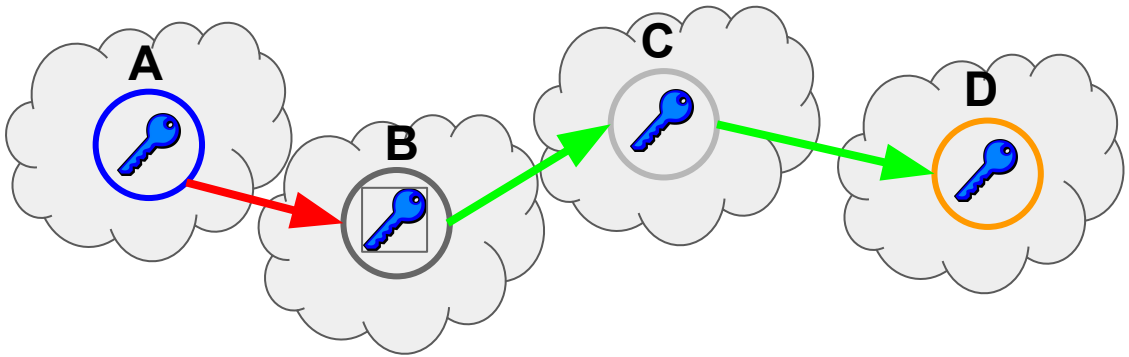
Protected DoTs



When it comes time to build a proof:

D can trivially decode the DoT from C to D because its under **D**’s key

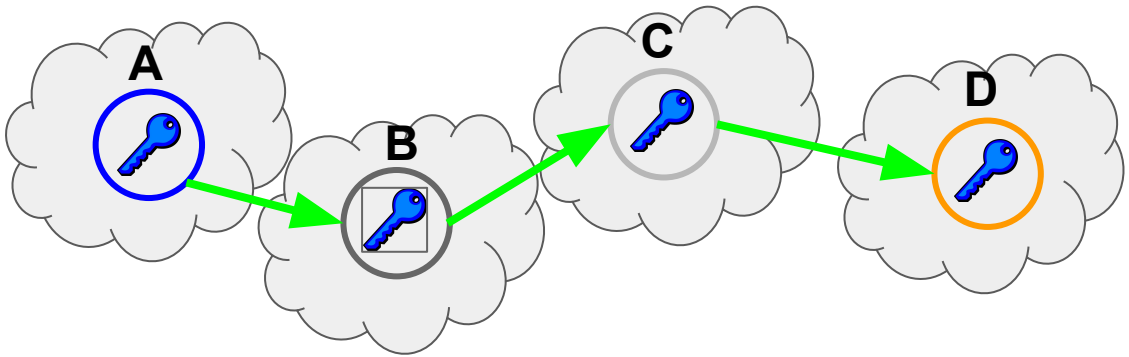
Protected DoTs



When it comes time to build a proof:

D can trivially decode the DoT from C to D because its under **D**'s key
Then **D** learns **C**'s private key, so can decode BC

Protected DoTs



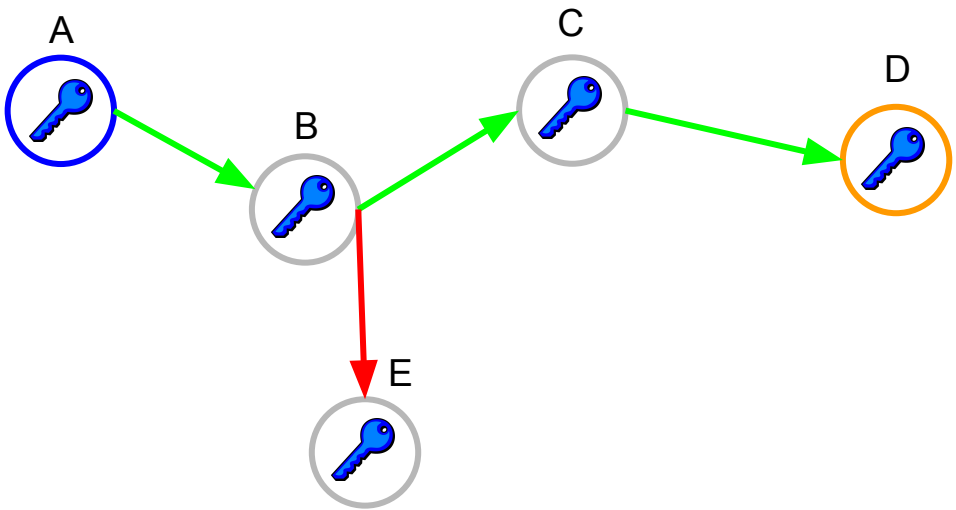
When it comes time to build a proof:

D can trivially decode the DoT from C to D because its under **D**'s key
Then **D** learns **C**'s private key, so can decode BC
Etc etc

Well yeah, but you could have done that ANYWAY

- Yes, you could have just sent your private key and used normal encryption, but then the recipient has a powerful private key
- This IBE private key:
  - Is only used for encrypting DOTs
  - Only in a single namespace
  - Only granting a specific set of permissions
  - That you were granted access to
- So only a minimal set of information is revealed

definitely-not-useful paths are not revealed



Other parts not presented here

CPU, memory and bandwidth usage on a variety of platforms under different scenarios (idle, normal, attack) and different internet characteristics (latency, speed)

City-scale (millions of people) emulation drawn from public San Francisco data

Very robust DDOS protection due to rapid, accurate traffic identification coupled with sybil-proof identities

>400 days of deployment across a handful of namespaces, hundreds of devices and tens of thousands of resources

Questions?

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