Cornerstone

Automating Remote NDN Entity Bootstrapping

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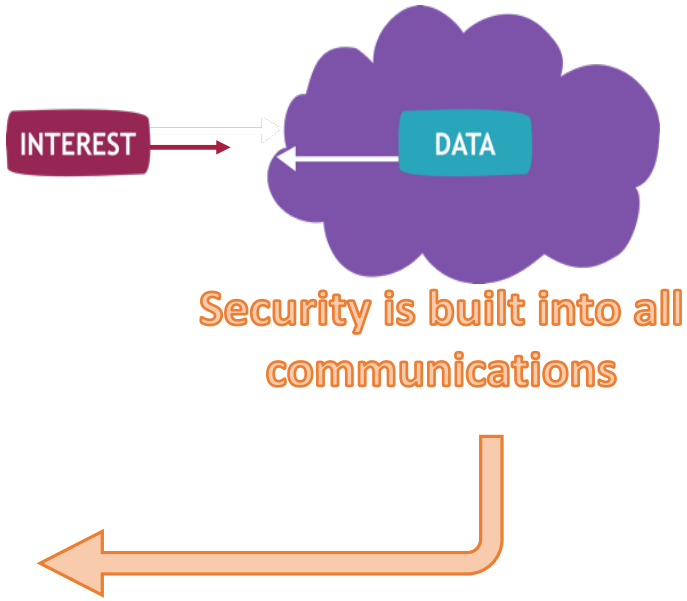
NDN: Named Data Networking

- **IP networking:** delivering packets to destination addresses

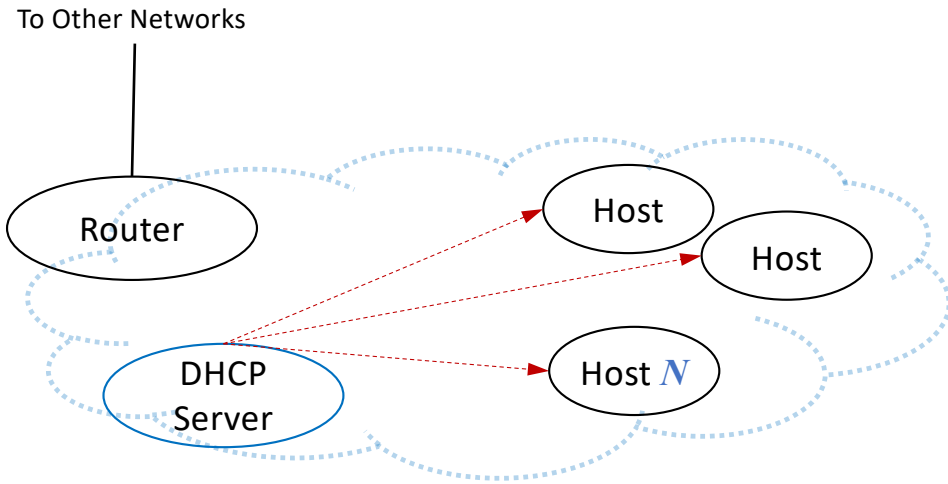
- **NDN networking:** fetching data by data names
  - Data with matching name can come from anywhere
  - Every data packet is cryptographically secured



- NDN needs a bootstrapping solution

Bootstrapping in a TCP/IP network

- An IP network is made of *interconnected nodes*, each identified by one (or multiple) IP address
- To connect a new IP node N into a network:
  N needs to go through a bootstrapping step first
  - DHCP server provides N with a set of connectivity parameters (its address, router address, etc)
  - IPv6: secure neighbor discovery based on CGA
- After bootstrapping: N can send & receive IP packets



Bootstrapping in an NDN Network

- An NDN network is made of *named entities* with *trust relations* among them

- Applications produce and consume *semantically named, secured* data
  - Each app process needs crypto credentials for signing, and security policies for verifying received data packets
    - Are they signed by the right key?

- To introduce a new NDN entity N into a network: N needs to go through a bootstrapping step first
  - To obtaining a set of security parameters (trust anchor, certificate, security policies, etc)
  - After bootstrapping: N can sign & verify data packets

- **Need a "DHCP-like" NDN bootstrapping solution**

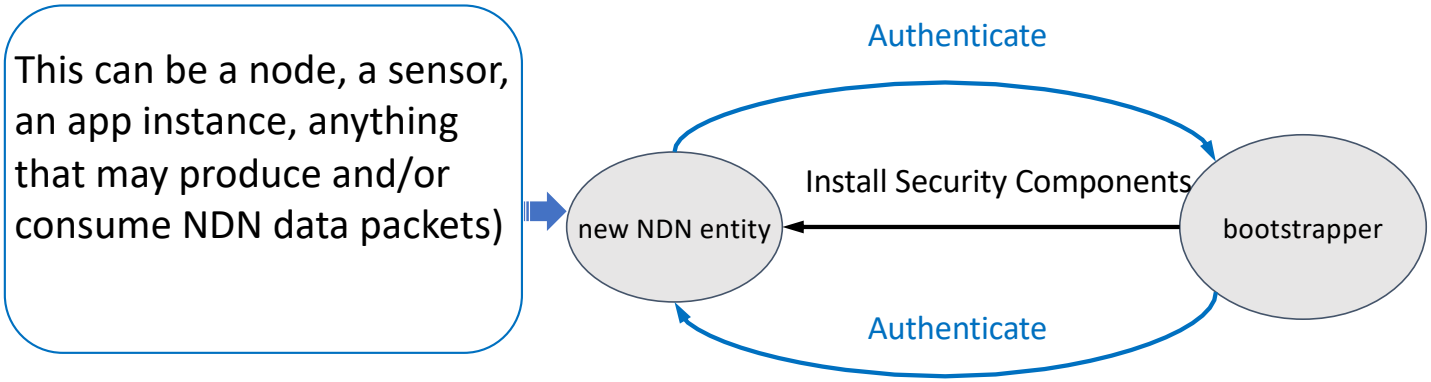
A side note:
does an IP network perform security bootstrapping?

- TCP/IP as designed has no security consideration
  - **IP bootstrapping** is all about **IP connectivity**
  - IPv6 secure neighbor discovery binds addresses to identities (public keys)

- Security solutions gradually introduced/patched on IP and TCP
  - IPSec, SSL/TLS, BGPSec, DNSSEC etc:
    they all need configuration of crypto credentials

- Common practice: manual or offline management of trust anchors
  - E.g., configuring Certificate Authorities into end hosts

Basic Steps in NDN Bootstrapping



- First perform mutual authentication
  - Bootstrapper verifies the authenticity of new entity
  - New entity makes sure it talks to the intended party

- Then bootstrapper installs security components into the new entity

Local versus Remote Applications

Previously, several works in building local apps

- NDN entities are local to the bootstrapper
- Direct WiFi or Bluetooth connectivity
- Within physical reach or the Line Of Sight
  - Smart homes, local file sharing, etc.

Local versus Remote Applications

- Recently, more works in building distributed apps
  → need for bootstrapping remote entities

- To bootstrap remotely located new entities
  - In an ideal NDN-native scenario
    - Remote entities already locally bootstrapped.
    - Mutual authentication by proving NDN certificate ownership

  - **At initial deployment:**
    new entities to be bootstrapped are reached via unsecured Internet connectivity
    - Health data sharing [ICN'22][1] : remote users; the data storage server is local to the bootstrapper
    - Federated, distributed storage system (more later): all users and file servers are remote

1. Dulal, Saurab, et al. "Building a secure mhealth data sharing infrastructure over ndn." *Proceedings of the 9th ACM Conference on Information-Centric Networking*. 2022.

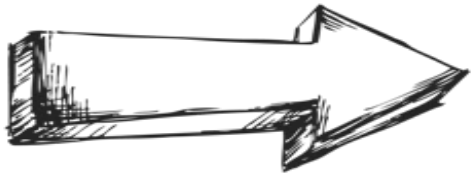
Local Bootstrapping: Solutions Exist
Remote Bootstrapping: New Problem

Smart Home

Local Bootstrapping:

New entity within physical vicinity, reachable through unsecured local connectivity

Authentication by QR code, vibration…



Collaborative Apps

Remote Bootstrapping:

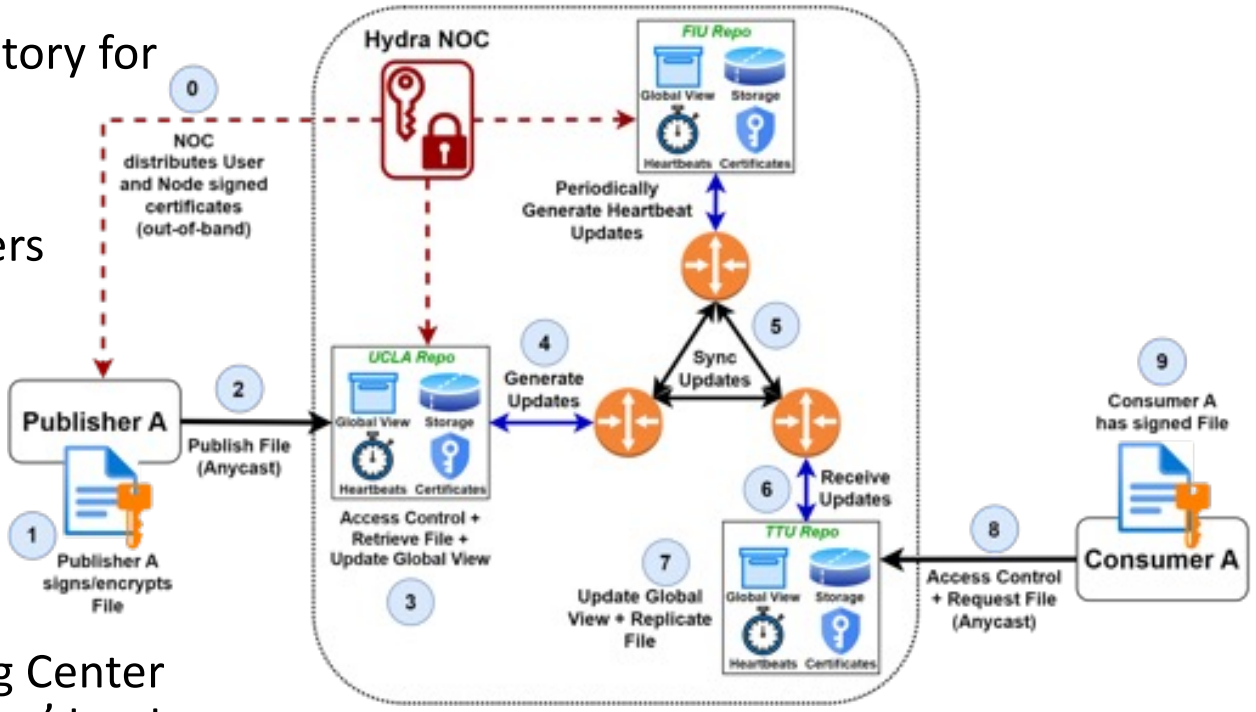
New entity only reachable through unsecured Internet

How to authenticate?

Approach: Starting from a specific application: ***Hydra***

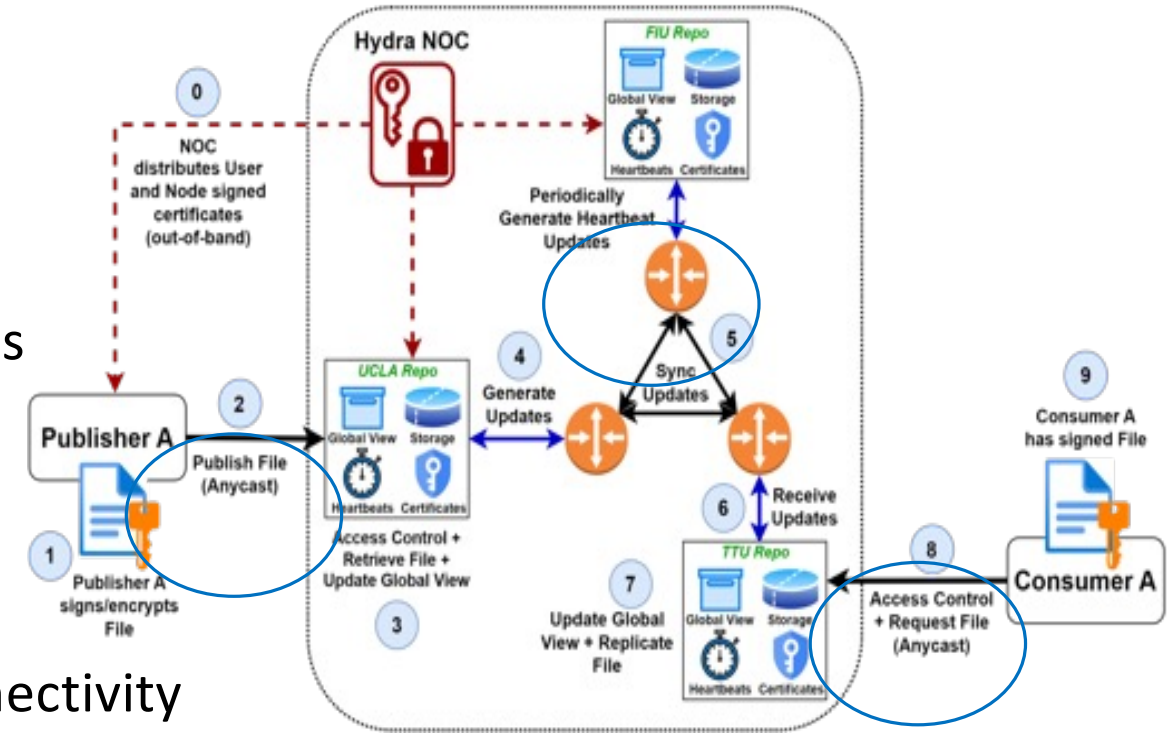
Hydra:
A Federated, Distributed Storage System over NDN

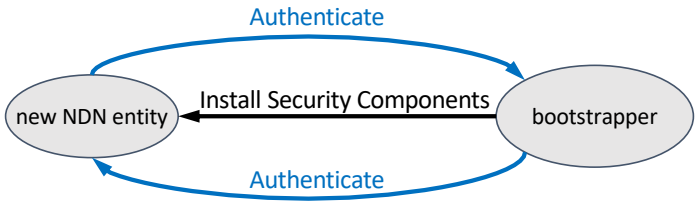
- A Decentralized Data Repository for Big Science Data
- Made of federated file servers contributed by participating organizations utilizing
  - Available storage resources at different organizations
  - NDN's built-in anycast for data access
- Hydra Networking Operating Center (NOC) manages Hydra entities' trust relations and read/write access



Bootstrapping Hydra Entities

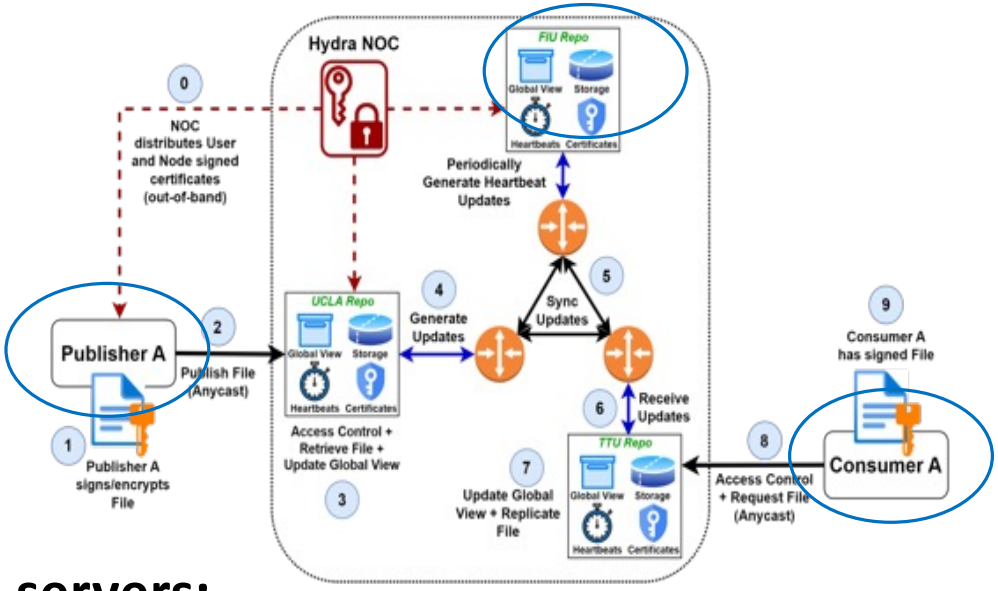
- Three types of Hydra entities
  - Data Publishers
  - Storage Servers
  - Data Consumers
- They can only be reached via unsecured Internet connectivity
  - How to perform remote authentication?





Our Solution

- **Data consumers:** anyone can fetch data from Hydra
  - No need to authenticate consumers
  - Consumers need to verify data: authenticate NOC, then fetch the Hydra trust anchor and security policies during bootstrapping



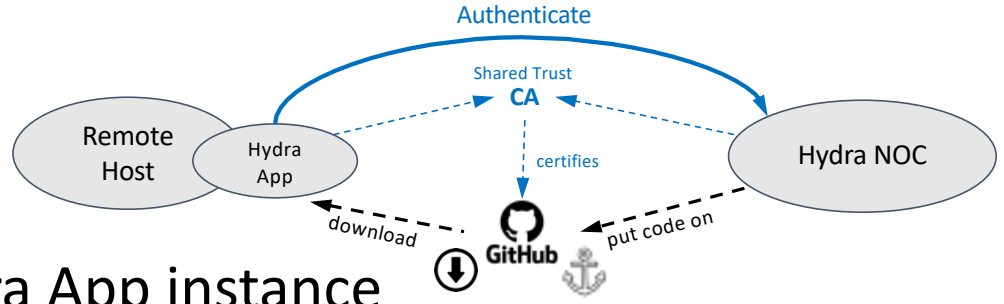
- **Data producing users and storage servers:** relying on existing trust relations in today's systems to perform remote authentications

Terminology

- **Trust Domain**
  - All Hydra entities form one Hydra trust domain, administrated by the Hydra NOC
- **Trust Anchor**
  - Hydra NOC certificate
  - Serve as the source of trust in Hydra operations
- **Certificate**
  - Issued to data producers and storage servers under their Hydra assigned names
- **Security Policies**
  - Defined by Hydra NOC, so that one knows how to verify received data (application files, coordination among data producers and storage servers)

Bootstrapping Step 1: Achieving Mutual Authentication

1. Hydra App instance authenticates Hydra NOC
   - Utilizing the authentication process of software distribution
     - Embedding Trust Anchor and Security Policies in Hydra app package
     - Requiring shared trust on software providers (e.g., GitHub, Ubuntu PPA, etc.)



2. Hydra NOC authenticates Hydra App instance
   - Servers have DNS names and TLS certificates
   - Users have their own Internet identifiers
     - Emails, identifiers from clouds
   - Membership control through identifier whitelist

Bootstrapping Step 2: Installing Security Components

- Installing Trust Anchor and initial Security policies during application installation
  - Initial security policies used for validating packet exchanges during bootstrapping
- Complete policies are fetched via Interest-Data exchange after bootstrapping
- Name Assignment
- Certificate Issuance

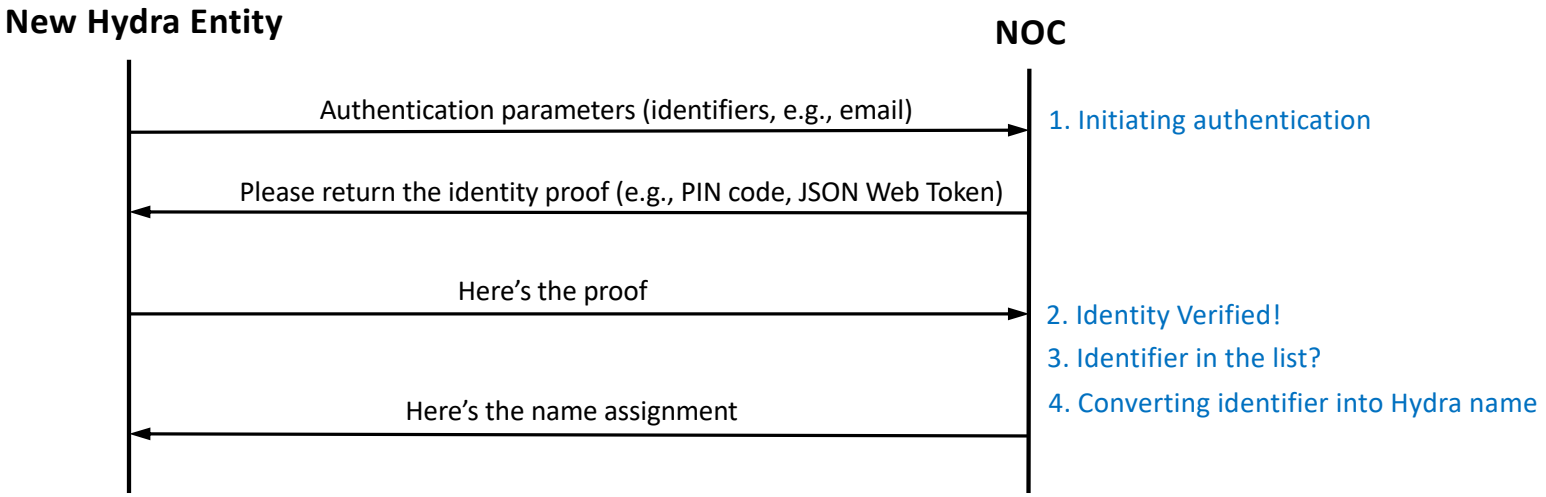
Name Assignment

- Each data producer and storage server is assigned a hydra name to ease the security policy definition (which makes use of semantic naming)
  - Storage server DNS name
    - `bruins.cs.ucla.edu`
  - Hydra name assigned to the storage server
    - `/hydra/node/edu/ucla/cs/bruins`

- Name assignment is automated using well defined naming conversion rules

Authentication and Naming Workflow

- Authentication Parameters
  - Server: DNS Name, User: email
- Identity Proof
  - Server: TLS Certificate
    User: PIN Code, JSON Web Token, SAML response, etc.



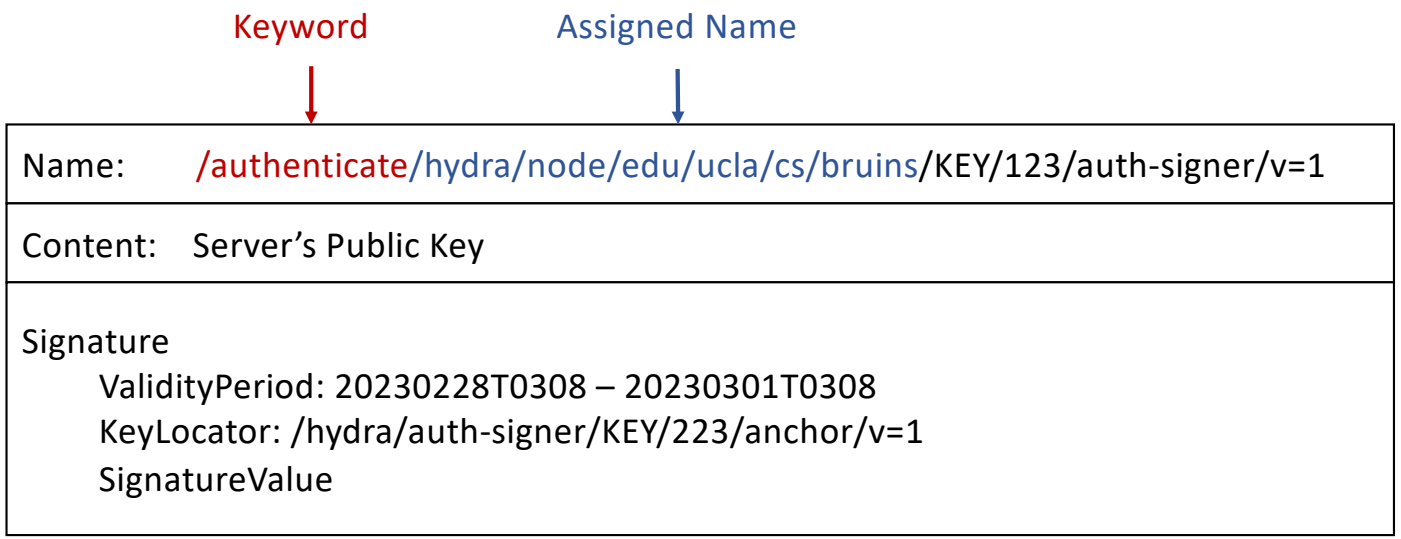
Certificate Issuance

- The requester has a name assignment
- The issuer
  - Requires the requester proving its name possession
  - Certifies the requester's name
- Today's Let's Encrypt
  - Asks the requester for Proof of Possession
    - By generating a DNS record, serving an HTTP object, …
    - Trusting the DNS and routing system
- Hydra's approach
  - Proof of Possession = NOC signed name assignment

Proof of Possession

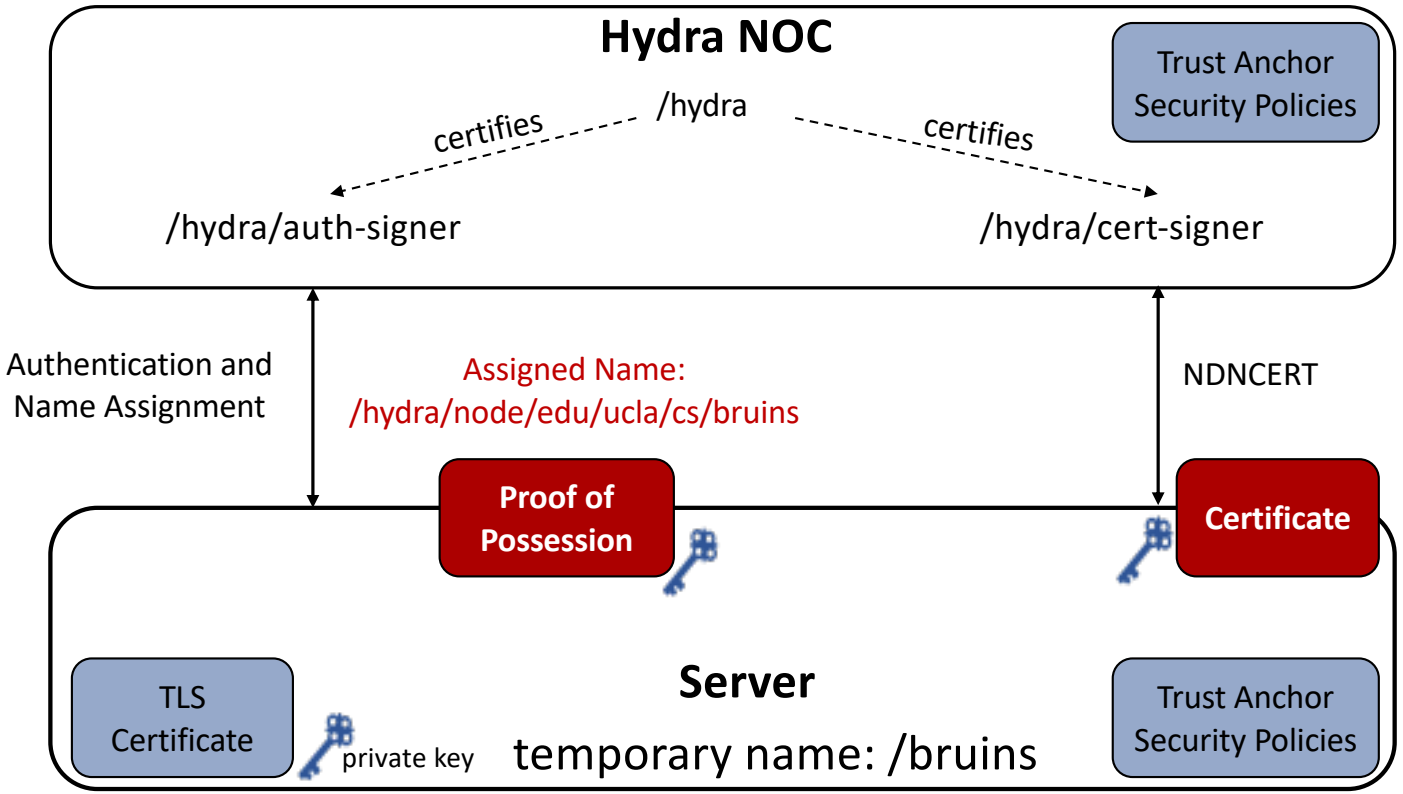
Hydra App proving it is a legit owner for a name

- Proving public key ownership == Proving the name possession
- NOC signed Data packet, in certificate format



Proof of Concept Implementation

https://github.com/tianyuan129/ndn-bootstrap



Configuring Hydra NOC

```
identity_config: /hydra
auth_config:
   user:
    whitelist : [alice@cs.ucla.edu, bob@ucla.edu]
   server:
    trust_anchors: /etc/ssl/certs
    whitelist: [bruins.cs.ucla.edu, suns.cs.ucla.edu]
validity_period: 3600s
```

Allowed User Email Addresses

Allowed CA Root

Allowed DNS Names

Proof of Possession Lifetime

Takeaway 1:
IP vs. NDN: Commonality in Bootstrapping

- Identify the necessary knowledge to be configured into bootstrapper
- Automate the rest to minimize human errors

DHCP

- Allocated IP address block to use
- Policy
  - e.g. setting MAC address restrictions
  - Lease durations
- Other DHCP options

NDN Bootstrapping

- Namespace to use
- Naming conventions
- Policy
  - Authentication rules
    - e.g. what/which entities to be admitted
  - Certificate lifetime

Takeaway 2:
Specifics in NDN Bootstrapping

- Before NDN gets widely deployed
  - Utilizing existing existing identifiers to authenticate remote entities
    - e.g. email address, DNS name
  - Utilizing the existing trust relations to carry out mutual authenticate between remote entities
    - e.g. trust the authenticity of files stored on git system

- Utilizing naming convention
  - Automates name assignment
  - Facilitates security policies definition