A DID (Decentralized Identifier) for Everything

DIDs as Unified Identifiers

Zero-Trust Computing

Inverted Computing Architectures

dDID (derived-DID)
DADi (Decentralized Autonomic Data item)

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Medici MedTalk 2019/08/22
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Early 2015 began designing decentralized reputation systems with data and algorithm provenance.

https://github.com/SmithSamuelM/Papers/blob/master/whitepapers/open-reputation-low-level-whitepaper.pdf

Needed decentralized identity infrastructure (2016+)

https://github.com/SmithSamuelM/Papers/blob/master/whitepapers/Identity-System-Essentials.pdf

Which led to decentralized identifiers (DIDs) (W3C) (2016+)

https://w3c-ccg.github.io/did-spec/ https://w3c-ccg.github.io/did-primer/

https://identity.foundation (68 Organizations) https://www.hyperledger.org/projects Indy Aries Ursa

Followed by verifiable credentials (VCs) (W3C) (2017+)

https://www.w3.org/TR/vc-data-model/

Combined with zero-trust computing (2017+)

https://github.com/SmithSamuelM/Papers/blob/master/whitepapers/ManyCubed.pdf

Which led to decentralized autonomic data (DAD) (2018+)

https://github.com/SmithSamuelM/Papers/blob/master/whitepapers/DecentralizedAutonomicData.pdf (RWOT6)

Which resulted in data flow chains with data & algorithm provenance (2018+)

https://github.com/SmithSamuelM/Papers/blob/master/whitepapers/A_DID_for_everything.pdf (RWOT7)

Distributed and Decentralized Computing Systems

distributed = computation happens at multiple sites

non-distributed = computation happens at one site

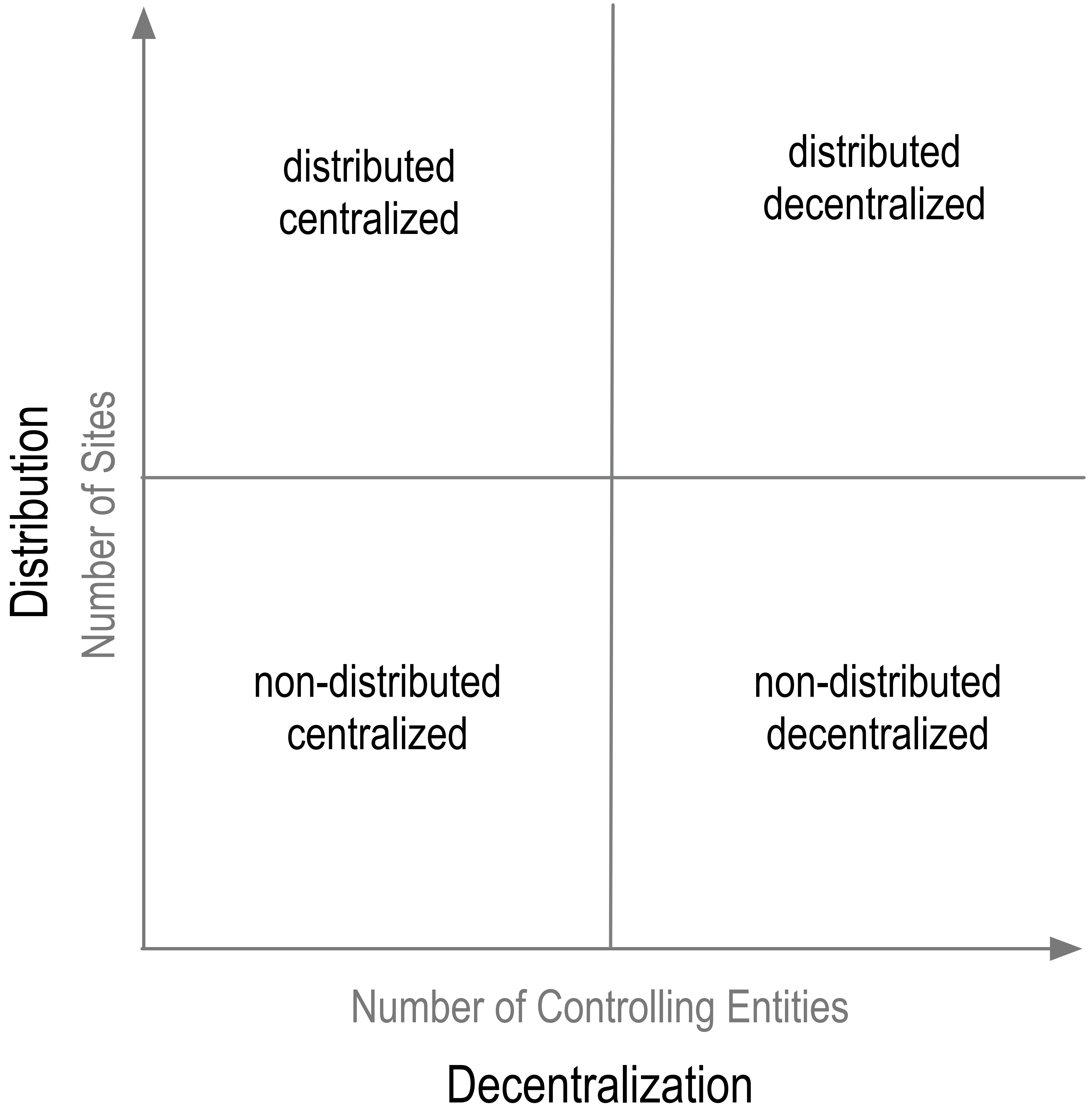
centralized = computation controlled by a single entity

decentralized = computation controlled by more than one entity

computing system may be some combination of *centralized* (*decentralized*) and distributed (*non-distributed*).

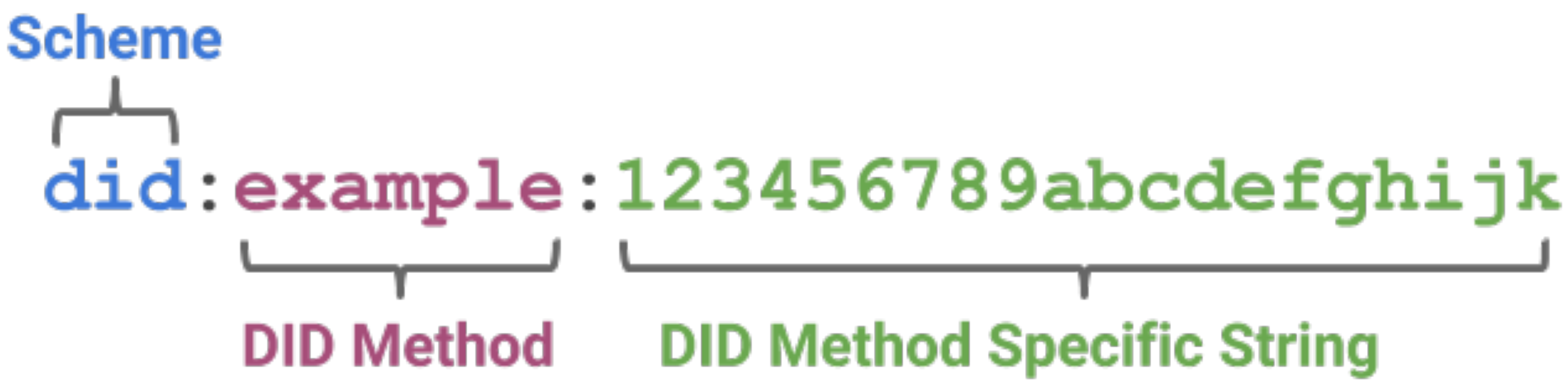
decentralization may occur to a degree.

- system decentralization may lie on a spectrum of strongly decentralized to weakly decentralized.


distributed centralized
distributed decentralized
non-distributed centralized
non-distributed decentralized
Distribution
Number of Sites
Number of Controlling Entities
Decentralization

DID = *UNIFIED* IDENTIFIER

https://w3c-ccg.github.io/did-spec/



Scheme

did:example:123456789abcdefghijk

DID Method

DID Method Specific String

did:*method*:*idstring*

did:*dad:Xq5YqaL6L48pf0fu7IUhL0JRaU2_RxFP0AL43wYn148=*

did:dad:Xq5YqaL6L48pf0fu7IUhL0JRaU2_RxFP0AL43wYn148=:blue

did:dad:Xq5YqaL6L48pf0fu7IUhL0JRaU2_RxFP0AL43wYn148=?who=me

did:dad:Xq5YqaL6L48pf0fu7IUhL0JRaU2_RxFP0AL43wYn148=:blue/my/stuff?name=sam#/foo/0

DDo = DID Document. Resolver lookup provides meta-data about DID.

Decentralized Distributed Data Streaming Applications

Decentralized = controlled by multiple entities

Distributed = spread across multiple compute nodes

Maintain provenance (chain-of-custody) for distributed data under decentralized control undergoing various processing stages that follows perimeter-less diffuse trust (zero-trust) security principles.

Zero-Trust Computing?

Resources:

NIST: Developing a Framework to Improve Critical Infrastructure Cybersecurity 04/08/2013 Zero Trust Model for Information Security, Forrester Research.

http://csrc.nist.gov/cyberframework/rfi_comments/040813_forrester_research.pdf

https://www.nist.gov/cyberframework

Zero Trust Networks 2017 Gilman & Barth

https://www.amazon.com/Zero-Trust-Networks-Building-Untrusted/dp/1491962194/ref=sr_1_1?s=books&ie=UTF8&qid=1499871379&sr=1-1&keywords=zero+trust+networks

Never trust always verify

No such thing as *zero* trust

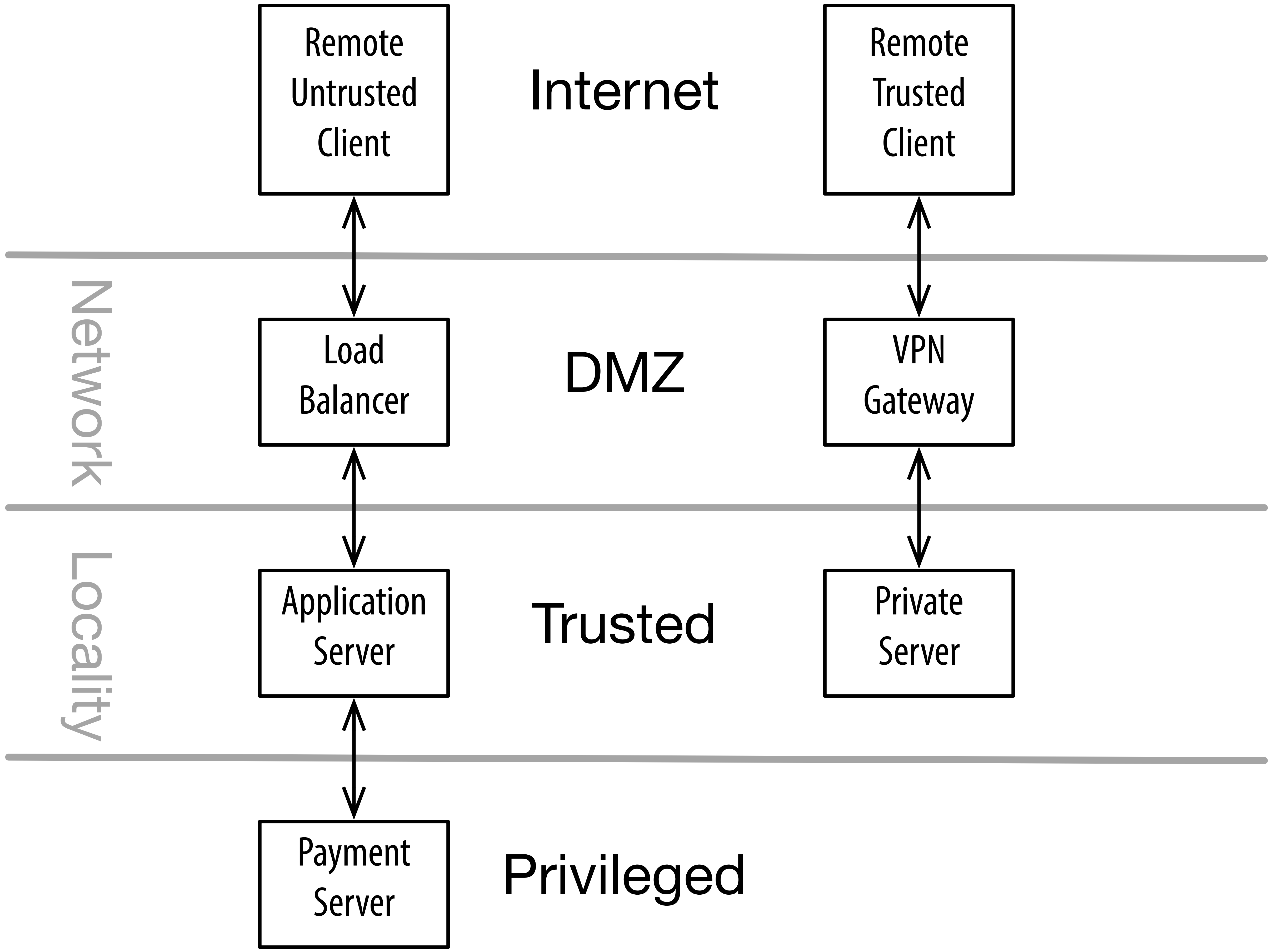
Really its *diffuse* trust when verified

Diffuse trust perimeter-less security model

Security Models

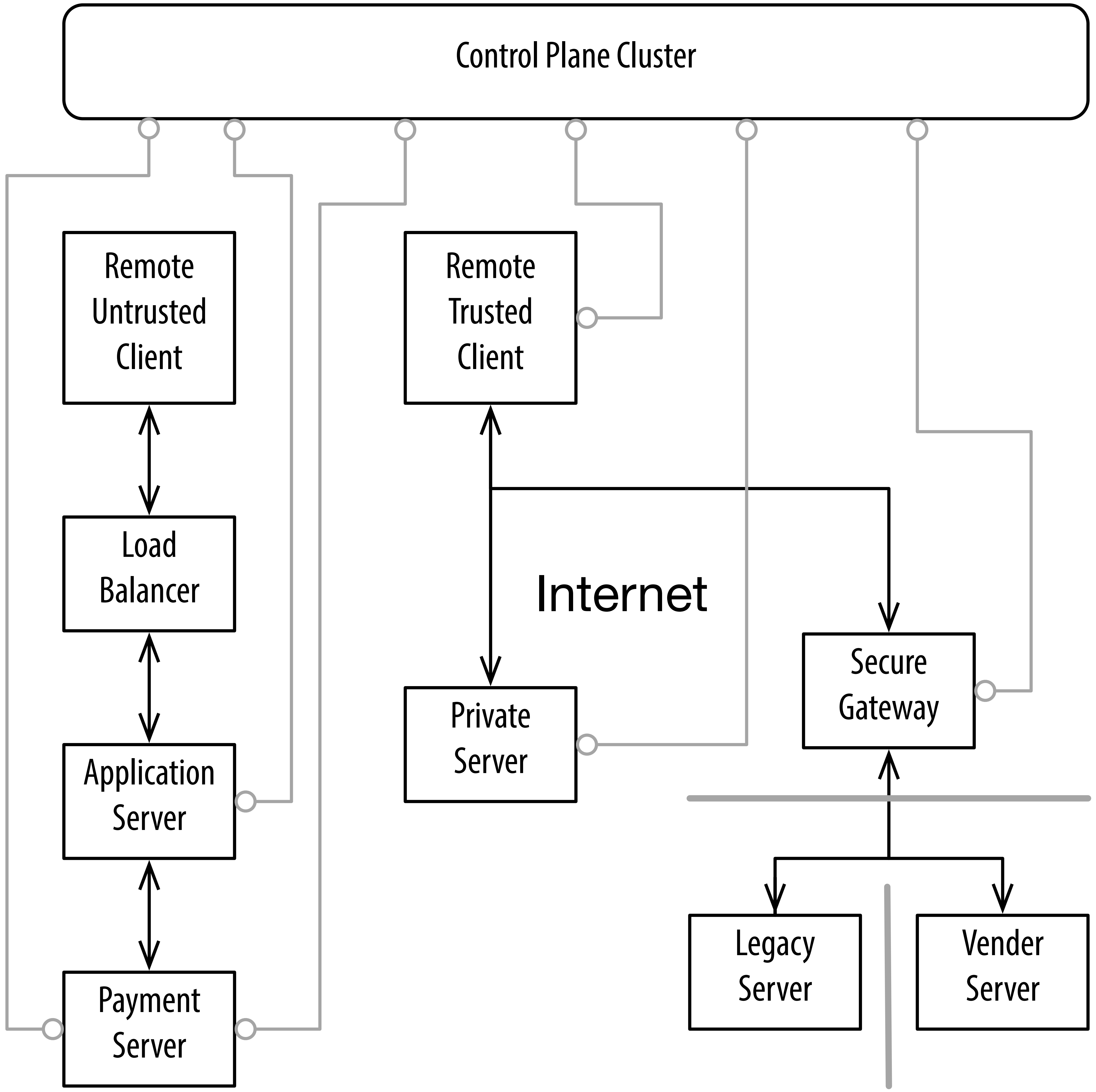
Locality Trust

Hard shells around Soft bodies



Zero Trust

Hard bodies everywhere



Diffuse trust perimeter-less security principles: 1

The network is always hostile both internally and externally.

Locality is not trustworthy.

Diffuse trust perimeter-less security principles: 2

By default, inter-host communication must be end-to-end signed/encrypted and data must be stored signed/encrypted using best practices cryptography.

Data is signed/encrypted in motion & at rest.

Diffuse trust perimeter-less security principles: 3

By default, every network interaction or data flow must be authenticated and authorized using best practices cryptography.

Verify every time for every thing.

Diffuse trust perimeter-less security principles: 4

Policies for authentication and authorization must be dynamically modified based on behavior (*reputation*).

Behavioral verification rules.

Diffuse trust perimeter-less security principles: 5

Policies must be governed by diffuse-trust distributed consensus.

Decentralized control.

Diffuse trust perimeter-less security principles: 6

By default, each data flow including all transformations must be end-to-end provenanced using decentralized identifiers (DIDs) and hence decentralized autonomic data items (DADis).

Dadify everything.

Diffuse trust perimeter-less security principles

Locality is not trustworthy.

Data is signed/encrypted/provenanced in motion & at rest.

Verify every time for every thing.

Behavioral verification rules.

Decentralized control.

Dadify everything.

DID = *UNIFIED* IDENTIFIER: 1

UUID: Universally Unique Identifier RFC 4122:

UUID type 1 -5

'9866eb78-1376-11e9-bab5-58ef68134e82'

16 byte collision resistant decentralized identifier generated with random number generator and optional name spacing data.

Enables distributed applications to create unique identifiers without central authority

Prefixed name spacing allows for sorting and searching properties such as:

time order, lexical order, nesting etc.

DID = *UNIFIED* IDENTIFIER: 2

URI: Uniform Resource Identifier,

URI: Uniform Resource Locator,

URN: Uniform Resource Name

RFC 3986

```
scheme:[//[user[:password]@]host[:port]][/path][?query][#fragment]
```

Enables specifying derived resources from central root.
Mini language for performing operations on resources (ReST).

DID = *UNIFIED* IDENTIFIER: 3

Decentralized Self-Certifying Identifier:

Contains fingerprint of public member of cryptographic public/private key pair.

Key pair is generated by user not central registry.

http://www.sigops.org/ew-history/1998/papers/mazieres.ps 1998

https://pdos.csail.mit.edu/~kaminsky/sfs-http.ps 1999

Enables decentralized self-sovereignty over identifier namespace

Control over namespace proven via signed assertion

Truly portable identifiers

If identifier is not portable then associated data and derived value is not portable

DID = *UNIFIED* IDENTIFIER: 4

Hierarchically Deterministic Derived Self-Certifying Identifier:

selfcertroot:/path/to/related/data?derivation=parent/child/child/child

Enables low friction creation of identifiers on demand without having to store private keys

DID = *UNIFIED* IDENTIFIER: 5

Public lookup services for identifier(s) to find meta-data associated with identifier.

Resolvable identifier meta data. Public decentralized resolvers.

Enables dynamic modification of identifier behavior and control

DID = *UNIFIED* IDENTIFIER: 6

Tupleizable (routable) Identifiers:

/channel/host/process/data = (channel, host, process, data)

Enables data flow routing overlay for distributed data processing systems.

Decentralized Identifiers Invert Compute Architectures

Conventional (centralized):

Server creates identifiers (GUID, Database primary keys)

Server timestamps

Event ordering relative to server

Server manages keys,

AuthN/AuthZ is indirect via client to server proxy

Perimeter security around servers

Server is source of truth

Server controls changes/updates to resources

Signed at rest problematic

Encrypted at rest problematic

Server's role is 2nd party in two-party transactions between client to server and server to client.

Unconventional (decentralized):

Client creates identifiers (DIDs)

Client timestamps

Event ordering relative to client or

vectorized relative to multiple clients or

consensual relative to distributed ledger

Client manages keys

AuthN/AuthZ is direct peer-to-peer

Perimeter-less security around clients

Client is source of truth

Client controls changes/updates to resources

Server cannot make changes

Client signs at rest

Client encrypts at rest

Server's role is either:

Trusted 3rd party in multi-party transactions between 2 (or more) clients and server as client

Agent or proxy for a client in two party transaction with another client.

DAD: Decentralized Autonomic Data

Decentralized: DID based. Governance of the data may reside with multiple parties. Trust in provenance is diffuse.

Autonomic: Self-managing or self-governing. Self-managing includes cryptographic techniques that make the data self-identifying, self-certifying, and self-securing.

Implies the use of cryptographic signatures as the root of trust and to maintain that trust over transformations of that data and its control.

Key management is thus a first order property of DAD.

3-Rs = *Reproduction, Rotation, and Recovery*:

Pre-rotation & Hybrid recovery methods.

Provenance for decentralized distributed data streaming including transformations

DADi: DAD item

Minimally Sufficient Means

Streaming data applications may impose significant performance demands on the processing of the associated data.

Desire efficient mechanisms for providing the autonomic properties of DAD .

DID, DDO, DADi, and dDID

DID = Decentralized Identifier

DDo = DID Document, resolver supplied meta-data about DID.

DADi = Decentralized Autonomic Data Item

Issues:

- Managing meta-data, control, and keys for many DADis
- DDo lookup and caching may be expensive
- DID/DDo pair per DADi may not be practical

dDID (derived DID) = Many unique identifiers derived from one root DID

One *root* DID/DDo provides meta-data for many dDIDs (HD Keychain)

```
did:dad:Xq5YqaL6L48pf0fu7IUhL0JRaU2_RxFP0AL43wYn148=:blue?chain=0/1

did:dad:Qt27fThWoNZsa88VrTkep6H-4HA8tr54sHON1vWl6FE=
```

Reproduction

```
did:dad:Xq5YqaL6L48pf0fu7IUhL0JRaU2_RxFP0AL43wYn148=?chain=0\1\2

did:dad:Qt27fThWoNZsa88VrTkep6H-4HA8tr54sHON1vWl6FE=
```

Simple privacy via unique cryptonym (dDID) per pair-wise relationship

Simple approach to generating large numbers of public dDIDS without having to store the associated private keys.

Only store the root private key

Minimally sufficient relative to more sophisticated methods such as zero knowledge proofs.

dDID Re-Generation

Public Derivation:

Client communicates with large number of public services

dDID is derived from root private key and public service identifier

Client does not need to store dDID but can re-derive on demand

On the fly dDIDs:

Data source is not identified so receiver generates dDID that is later correlated to or claimed by the data source

dDID Management

dDID NameSpacing with HD-path: root + namespace + hd path

```
did:dad:Xq5YqaL6L48pf0fu7IUhL0JRaU2_RxFP0AL43wYn148=:blue?chain=0/1
did:dad:Xq5YqaL6L48pf0fu7IUhL0JRaU2_RxFP0AL43wYn148=:red?chain=0/1
```

dDID Sequencing: dDID + sequence number

```
did:dad:Qt27fThWoNZsa88VrTkep6H-4HA8tr54sHON1vWl6FE=/10057
```

dDID Database

index = anonymous dDID,

value = derivation path from root DID

```
{
    "did:dad:Qt27fThWoNZsa88VrTkep6H-4HA8tr54sHON1vWl6FE=":
    "did:dad:Xq5YqaL6L48pf0fu7IUhL0JRaU2_RxFP0AL43wYn148=?chain=0\1\2",
    ...
}
```

Example Signed DADi

```
{
    "id": "did:dad:Xq5YqaL6L48pf0fu7IUhL0JRaU2_RxFP0AL43wYn148=",
    "data":
    {
        "name": "John Smith",
        "nation": "USA"
    }
}
\r\n\r\n
u72j9aKHgz99f0K8pSkMnyqwvEr_3rpS_z2034L99sTWrMIIJGQPbVuIJ1cupo6cfIf_KCB5ecVRYoFRzAPnAQ==
```

Change Detection

Prevent replay attacks: either or both:

- sequence number in dDID
- *changed* field with monotonically increasing sequence number or date time

```
{
    "id": "did:dad:Qt27fThWoNZsa88VrTkep6H-4HA8tr54sHON1vWl6FE=/10057",
    "changed" : "2000-01-01T00:00:00+00:00",
    "data":
    {
        "temp": 50,
        "time": "12:15:35"
    }
}
\r\n\r\n
u72j9aKHgz99f0K8pSkMnyqwvEr_3rpS_z2034L99sTWrMIIJGQPbVuIJ1cupo6cfIf_KCB5ecVRYoFRzAPnAQ==
```

Entity

Something that has a distinct and independent existence either in the real or the digital world. Examples of an entity are:

Living Organism

Physical Object

Locations or Events

Machines and Devices in the Internet of Things (IoT)

Digital Asset, Data Set or Agent

Data Flow Provenance

Mechanism for tracing data item content and control (chain-of-custody) through a processing system including any transformations to the data item or its governance.

Includes flows with multiple sources and sinks of data, independently and in combination.

Includes verifying the end-to-end integrity of every data flow including any transformations (additions, deletions, modifications, and combinations).

An entity's influence on an application is solely based on the digital data flows that move between the entity and the other components of the distributed application.

These data flows are the entity's *projection* onto the distributed application.

If those projections consist of *DADis* and every interaction of internal components consists of *DADis* then we have a universal approach for implementing decentralized applications with total provenance of control and data within the application.

Chaining up DADi

Self-contained virtual blockchain of the data.

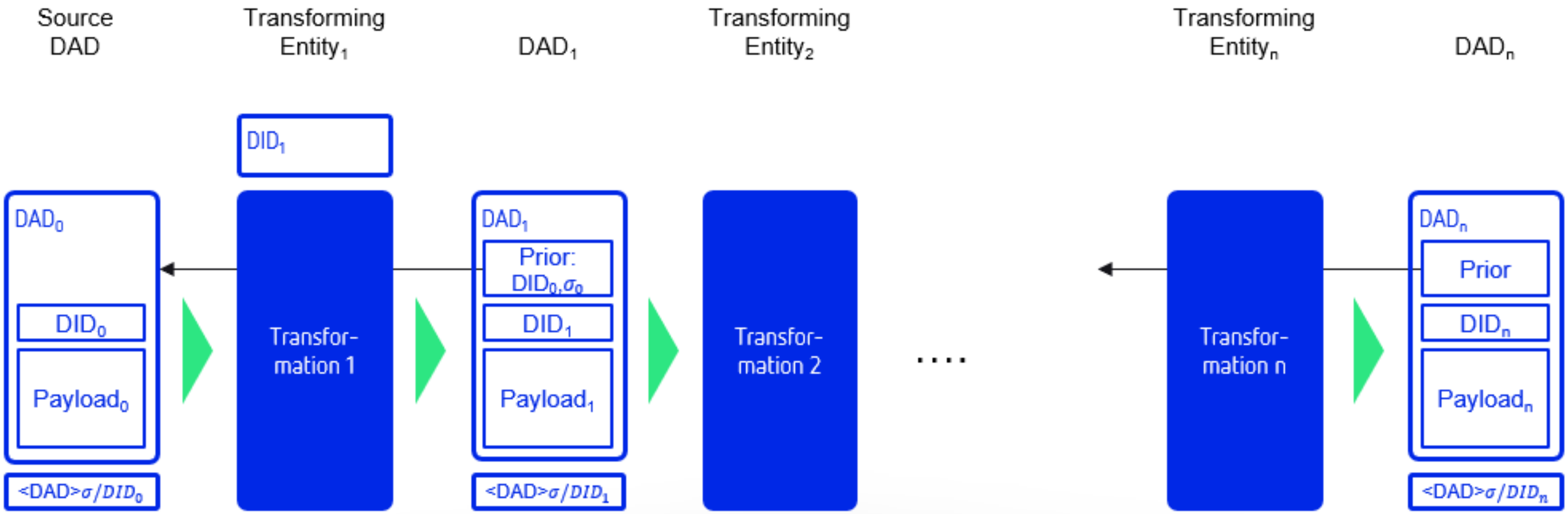
IDs and signatures link transformation steps. (control and/or value)

Provides integrity and non-repudiation.

Use associated database to verify complete chain.

Chaining up DADi Diagram Linear

Linear Decentral Autonomic Data Flow – Self-contained DAD Chain



Chaining up DADi Example

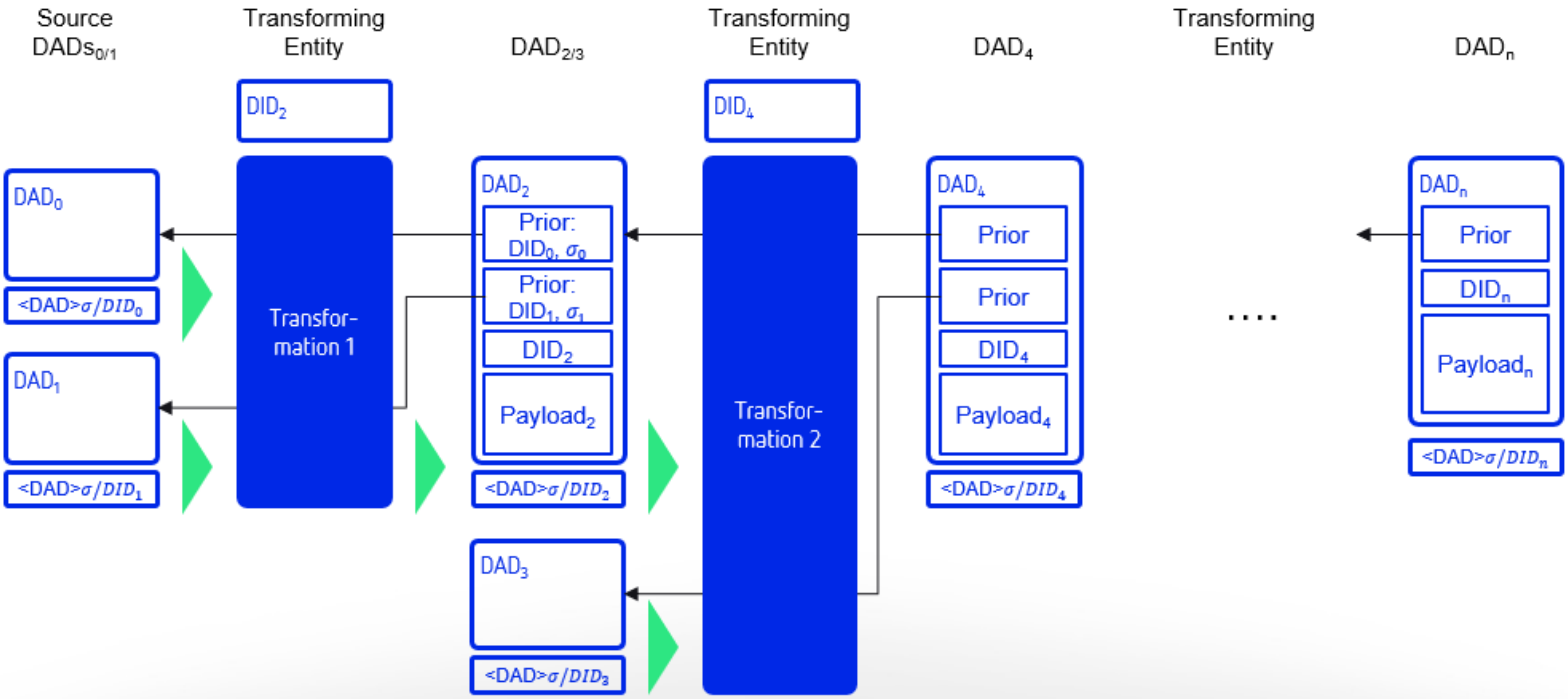
```
{
    "id": "did:dad:Qt27fThWoNZsa88VrTkep6H-4HA8tr54sHON1vWl6FE=/alpha/10057",
    "changed" : "2000-01-01T00:00:00+00:00",
    "data":
    {
        "temp": 50,
        "time": "12:15:35"
    }
}\r\n\r\n
u72j9aKHgz99f0K8pSkMnyqwvEr_3rpS_z2034L99sTWrMIIJGQPbVuIJ1cupo6cfIf_KCB5ecVRYoFRzAPnAQ==
```

```
{
    "id": "did:dad:AbC7fThWoNZsa88VrTkep6H-4HA8tr54sHON1vWl6FE=/beta/10057",
    "changed" : "2000-01-01T00:00:02+00:00",
    "data":
    {
        "temp": 50,
        "humid": 87,
        "time": "12:15:37"
           }
 "prior",
         {
                "id":  "did:dad:Qt27fThWoNZsa88VrTkep6H-4HA8tr54sHON1vWl6FE=/alpha/10057",
               "sig": u72j9aKHgz99f0K8pSkMnyqwvEr_3rpS_z2034L99sTWrMIIJGQPbVuIJ1cupo6cfIf_KCB5ecVRYoFRzAPnAQ==

}\r\n\r\n
wbcj9aKHgz99f0K8pSkMnyqwvEr_3rpS_z2034L99sTWrMIIJGQPbVuIJ1cupo6cfIf_KCB5ecVRYoFRzAPnAQ==
```

Chaining up DADi Diagram Multiplex

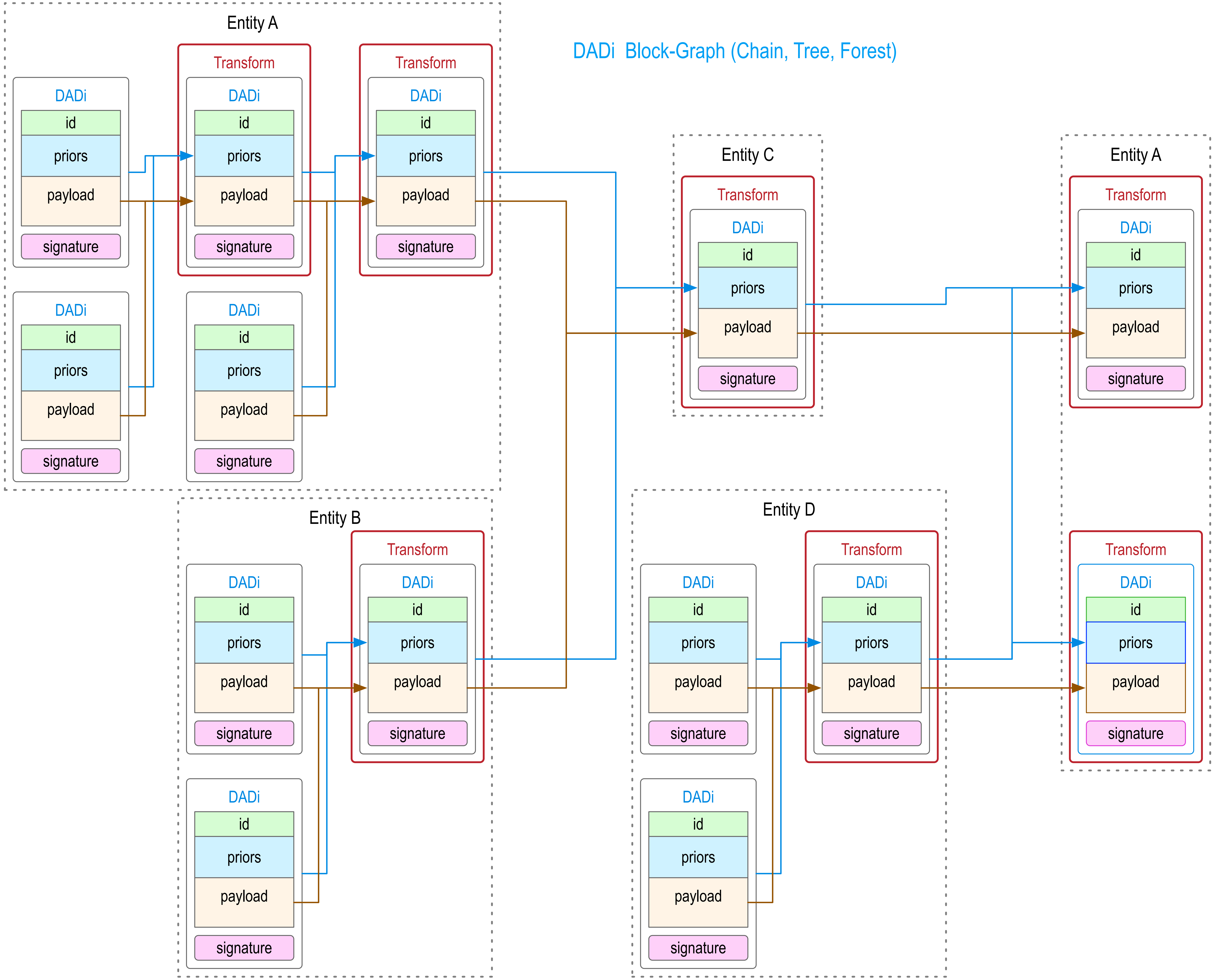
DAG Decentral Autonomic Data Flow – Self-contained DAD Graph



Chaining up DADi Example Multiplex

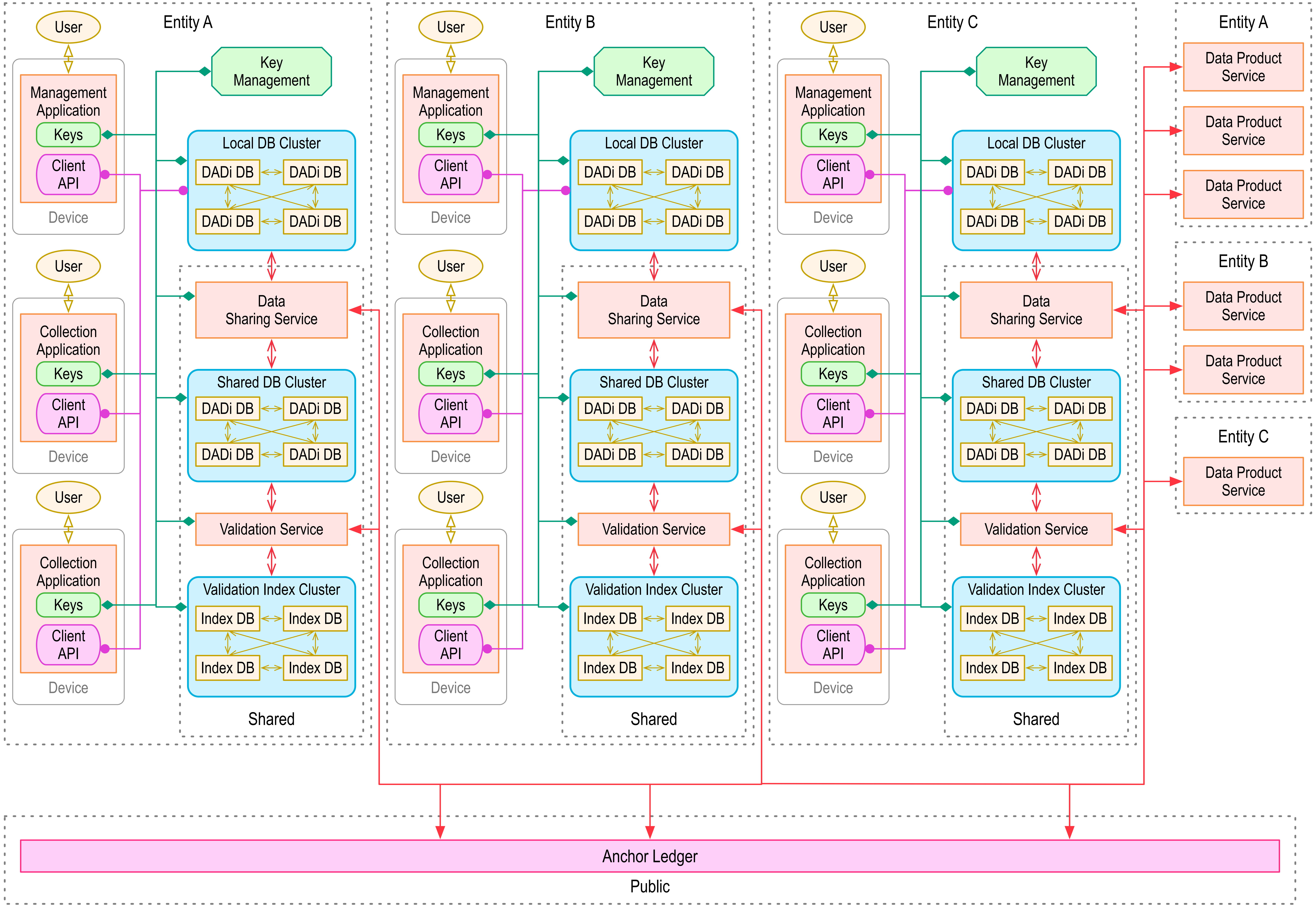
```
{
    "id": "did:dad:AbC7fThWoNZsa88VrTkep6H-4HA8tr54sHON1vWl6FE=/gamma/10057",
    "changed" : "2000-01-01T00:00:03+00:00",
    "data":
    {
        "Avg temp": 55,
        "time": "12:15:39"
  }
      "priors",
         [
           {
                "id":  "did:dad:Qt27fThWoNZsa88VrTkep6H-4HA8tr54sHON1vWl6FE=/alpha/10057",
               "sig":
u72j9aKHgz99f0K8pSkMnyqwvEr_3rpS_z2034L99sTWrMIIJGQPbVuIJ1cupo6cfIf_KCB5ecVRYoFRzAPnAQ==
      },
{
                "id":  "did:dad:WA27fThWoNZsa88VrTkep6H-4HA8tr54sHON1vWl6FE=/beta/10058",
               "sig":
j78j9aKHgz99f0K8pSkMnyqwvEr_3rpS_z2034L99sTWrMIIJGQPbVuIJ1cupo6cfIf_KCB5ecVRYoFRzAPnAQ==
      },
]
}\r\n\r\n
dy3j9aKHgz99f0K8pSkMnyqwvEr_3rpS_z2034L99sTWrMIIJGQPbVuIJ1cupo6cfIf_KCB5ecVRYoFRzAPnAQ==
```

Chaining up DADi Block Graph



Chaining up DADi Architecture

Decentralized Data Chain-of-Custody Architecture



Conclusion & Discussion

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Dependency Inversion Principle

Dependency Inversion Principle, Martin 1996

Bad Software Design: Software that fulfills its requirements but exhibits any or all of:

Rigidity: Hard to change because each change affects other parts of the system.

Fragility: Making a change causes other parts of the system to break.

Immobility: Hard to disentangle in order to reuse in another application.

DIP:

HIGH LEVEL MODULES SHOULD NOT DEPEND UPON LOW LEVEL MODULES.

BOTH SHOULD DEPEND UPON ABSTRACTIONS.

ABSTRACTIONS SHOULD NOT DEPEND UPON DETAILS.

DETAILS SHOULD DEPEND UPON ABSTRACTIONS.

Its all about dependency management, duh !!!

Dependency Inversion Principle Transcendence

Bad Software Design: Software that fulfills its requirements but exhibits any or all of:

Rigidity: Hard to change because each change affects other parts of the system.

Fragility: Making a change causes other parts of the system to break.

Immobility: Hard to disentangle in order to reuse in another application.

Flow Based DAD transcends the DIP thusly:

THERE ARE NO MODULES, JUST COMPONENTS

THERE ARE NO ABSTRACTIONS OR DETAILS JUST DATA

COMPONENTS DEPEND ON DATA, NOT OTHER COMPONENTS