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# Distributed Systems
## Name and Directory Services

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# Agenda

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# Introduction

- Numerical identifiers and addresses (e.g., IP addresses) are difficult to memorize for human users
- Names provide an abstraction of the concrete services and objects

→ But how can we get from a name to its address?

- Remember: In the previous chapter we saw how a binder deals with naming and locating for an RPC system
- More general we require:
  - Name services
  - Directory services
- Name resolution does exist in other IT contexts (e.g., variable name → memory address)

# Agenda

# Names

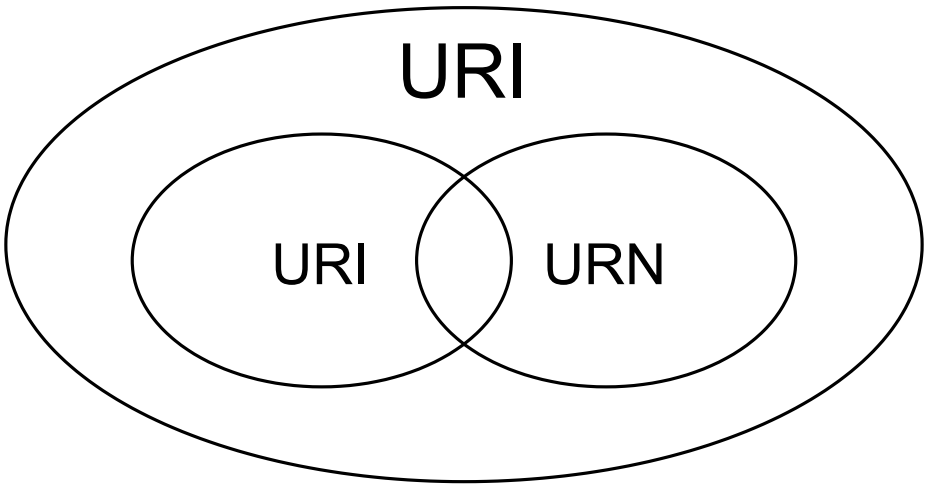
- **Names**
  - Names are used to **identify** objects (e.g., a resource or service)
  - A name is a sequence of bits or characters
  - Binding: the process which binds a name to an object
- **Name properties**
  - **unique**: a name identifies exactly one object unambiguously
  - **pure**: a name is only a bit pattern and does not convey any other information
  - **impure**: a name implies additional information about the specified object

# Examples

- **unique**
  - "'Joe Smith"' is not unique
    - → A name in combination with birthday and location of birth is typically unique
  - **UUIDs (Universally Unique Identifiers)** are unique
    - 128 bit number
    - Specified in RFC 4122 and ITU-T Rec. X.667 | ISO/IEC 9834-8:2005
    - Various versions exist
    - Can be generated, for instance, by the tool `uuidgen`
    - In Microsoft ecosystem also called **Global Unique Identifier (GUID)**
    - Example: `123e4567-e89b-12d3-a456-426614174000`
- **pure**
  - UUIDs as names of DCOM objects or classes are pure
- **impure**
  - DNS names often imply additional information
    - e.g., `mail.fra-uas.de`

# URI, URL, and URN

- A **Uniform Resource Identifier (URI)** identifies a specific resource, e.g., `ISBN 978-1543057386`
- A **Uniform Resource Locator (URL)** additionally specifies how the resource can be accessed,
  e.g.,
  `https://www.libra-buchhandlung.de/shop/item/9780131217867`
- A **Uniform Resource Name (URN)** identifies a specific resource in a persistent and location-independent way,
  e.g., `urn:isbn:978-1543057386`

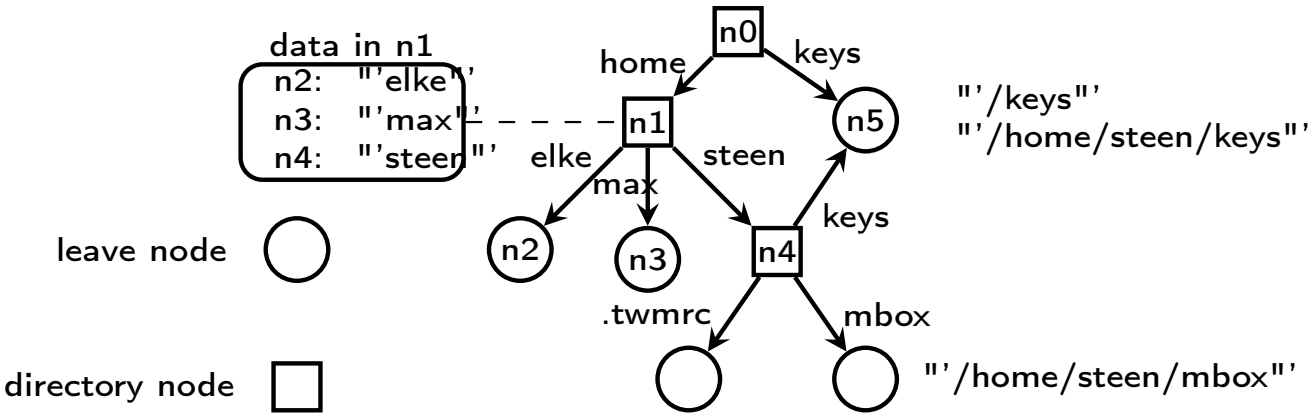


# Name Spaces

- Names have their meaning only in a certain **context**
- Names are structures in **name spaces**
- Name spaces define the syntax rules for the names
- Examples: Name spaces in C++, DNS, ISBN ...

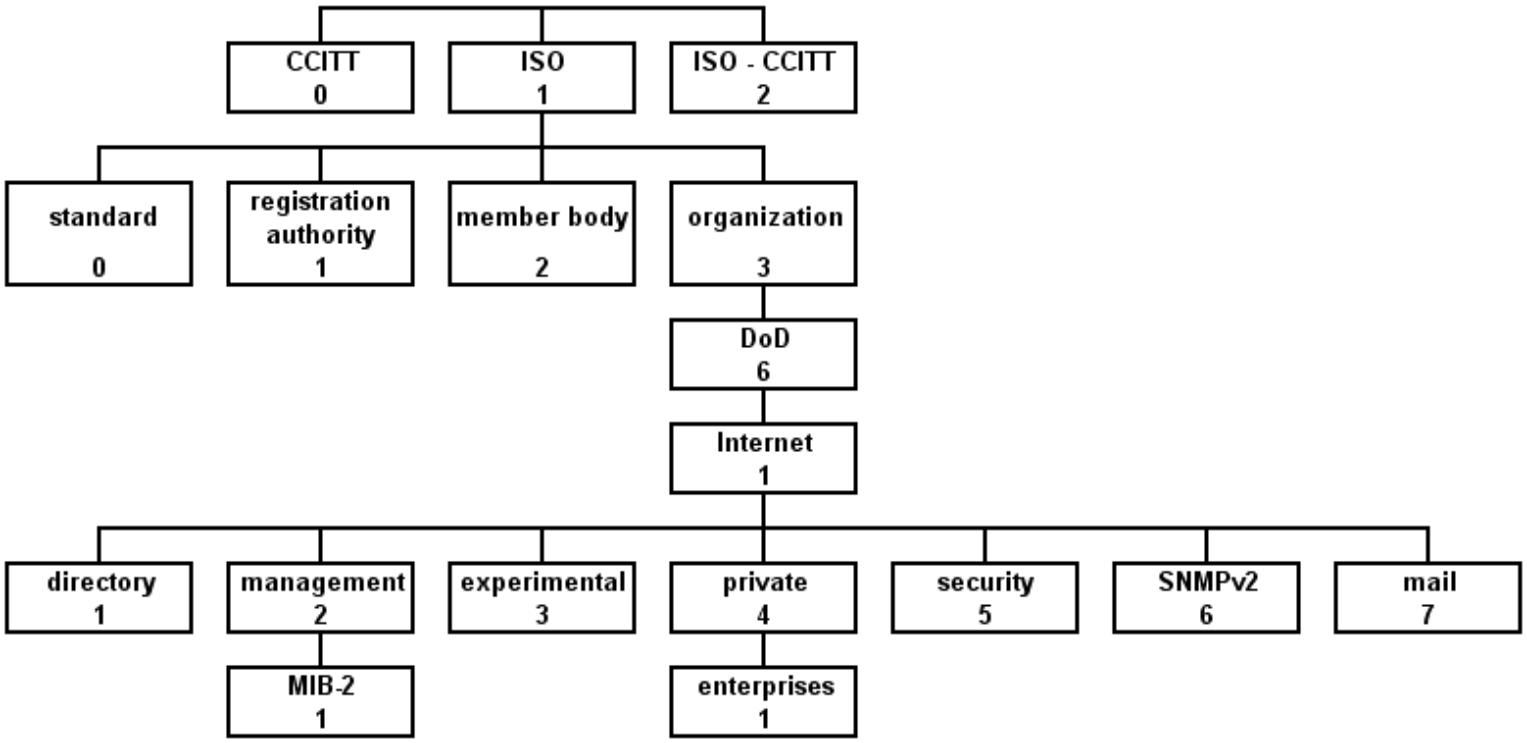
# Name Space Structures

- Flat name spaces (less common today, e.g., Unix UIDs)
- Hierarchical name spaces are typically organized as directed graphs with labels
- In these name spaces the context is given by the prefix
  - Directory nodes and leaves
  - Absolute and relative paths
  - Global and local names
- Example: Unix file system name spaces



# Example: MIB-2 Name Space

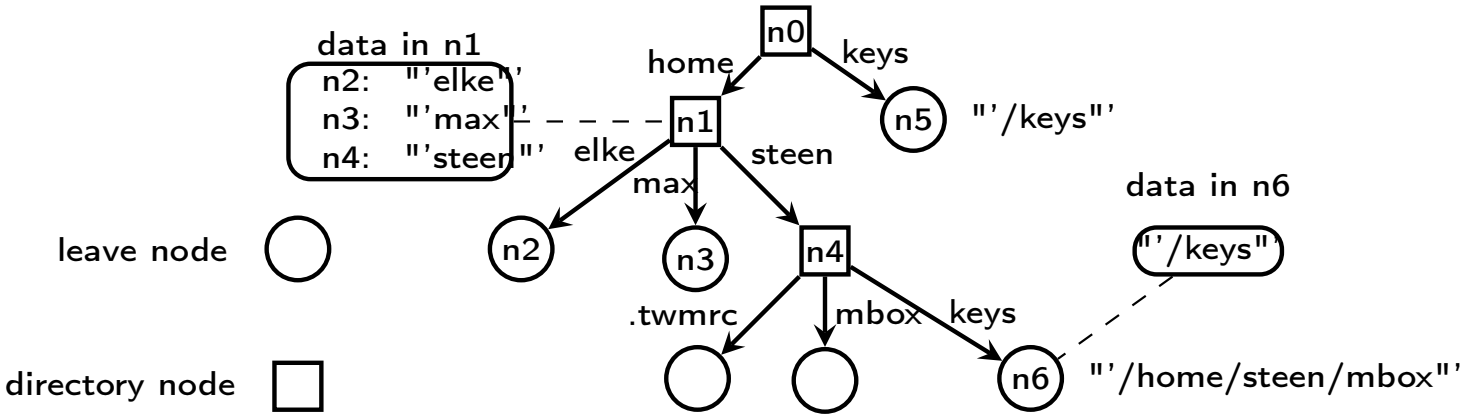
- MIB: Management Information Base




https://upload.wikimedia.org/wikipedia/commons/1/1c/SNMP.MIB-Tree.PNG

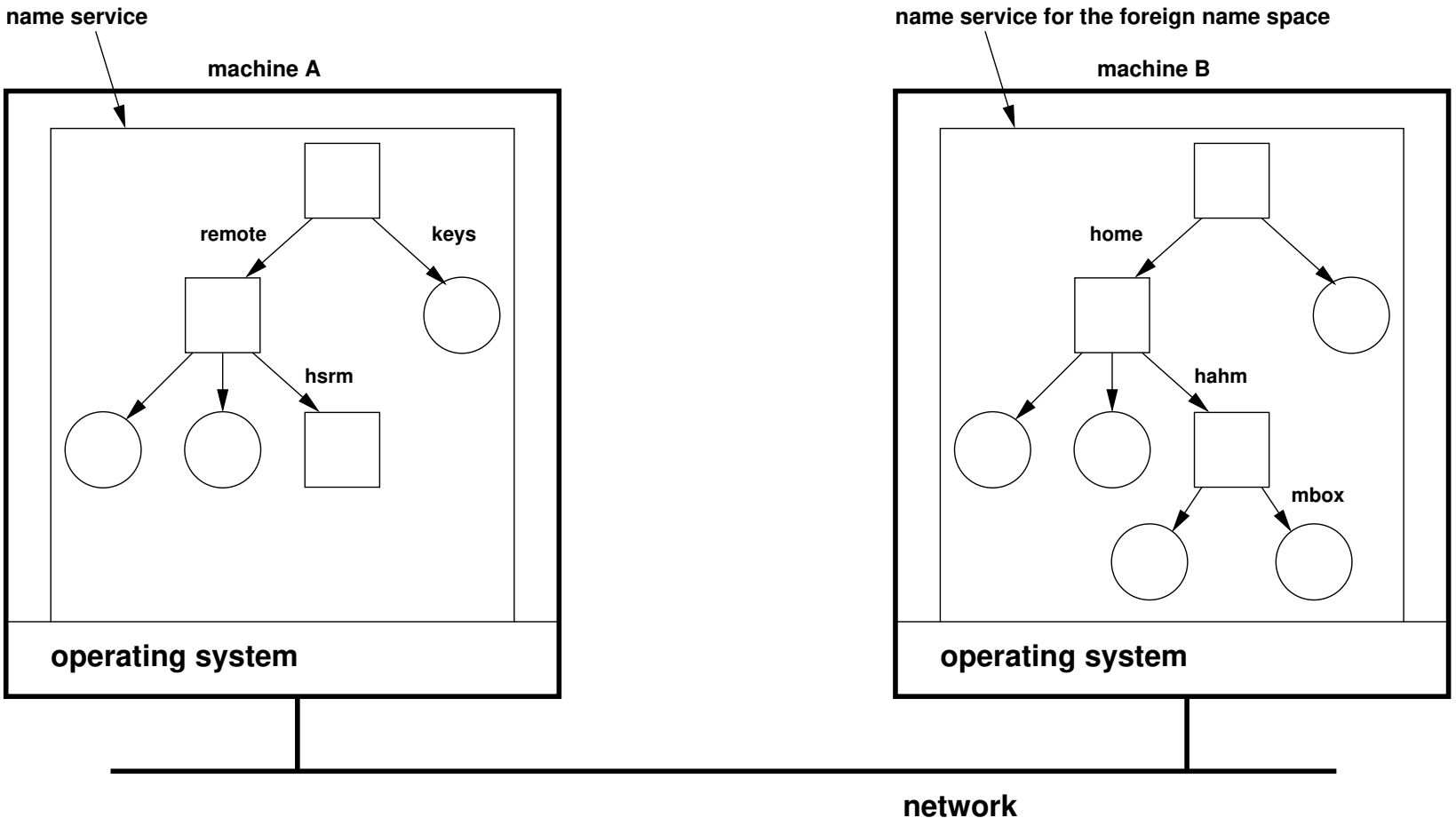
# Links in a Name Space

- The name of an object is another name
- Forwarding or mapping of a name to another name
- Example: Unix soft link



# Links into Another Name Space

- Mounting



# Links into Another Name Space

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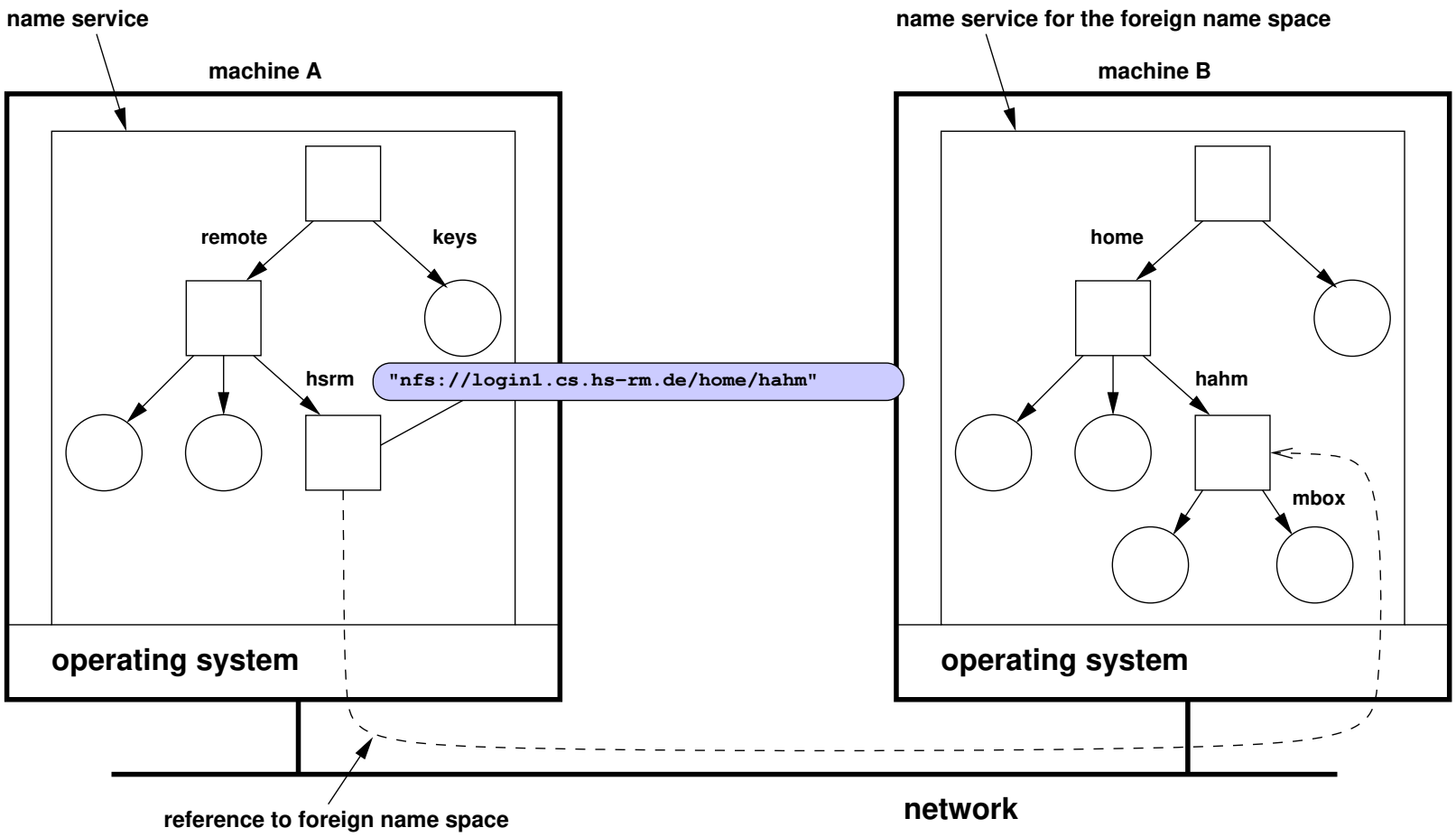


# Organisation of Huge Name spaces

- To manage huge name spaces effectively, these are typically divided into three layers:
  - Global Layer
    - High-level nodes (entry points)
  - Administrative Layer
    - Name spaces within an organization
  - Managerial Layer
    - Name spaces for names that frequently change
- Properties:

| | **Global** | **Administrational** | **Managerial** |
|---|---|---|---|
| Geographical scale of network | Worldwide | Organization | Department |
| Total number of nodes | Few | Many | Vast numbers |
| Responsiveness to lookups | Seconds | Milliseconds | Immediate |
| Update propagation | Lazy | Immediate | Immediate |
| Number of replicas | Many | None or few | None |
| Is client-side caching applied? | Yes | Yes | Sometimes |

# Example: DNS (Domain Name Service)

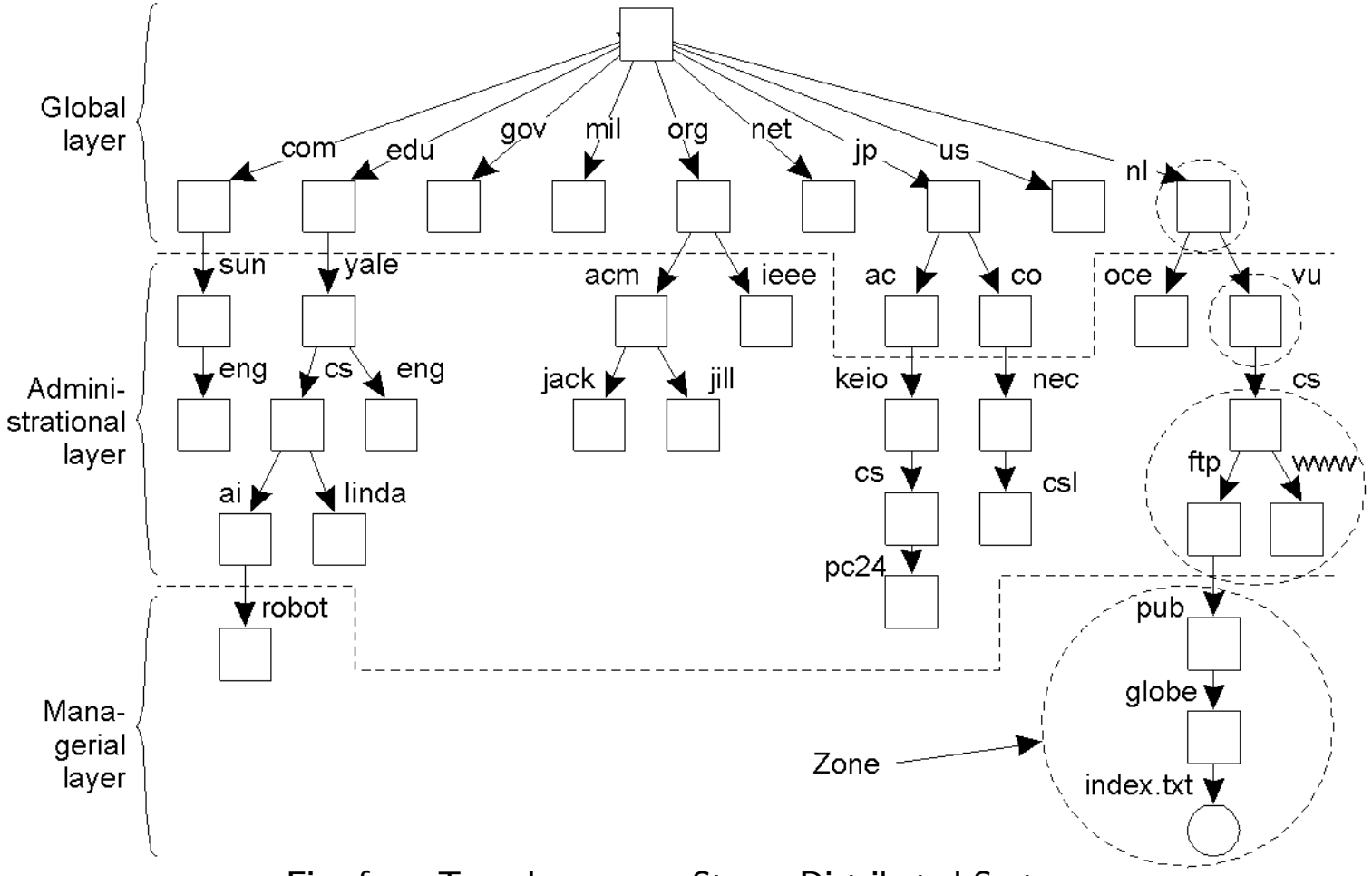



Fig. from Tanenbaum, van Steen: Distributed Systems

# Addresses

- Addresses are **attributes of names** which can be used to interact with or access objects
  - Examples for addresses
    - Street, house number, city
    - Phone number
    - IP address or (IP address, port number)
    - Memory address
- Advantage for the use of names over addresses
  - Location independent (preferable)
  - Easier to memorize
  - Abstracts from many (protocol) details of an address

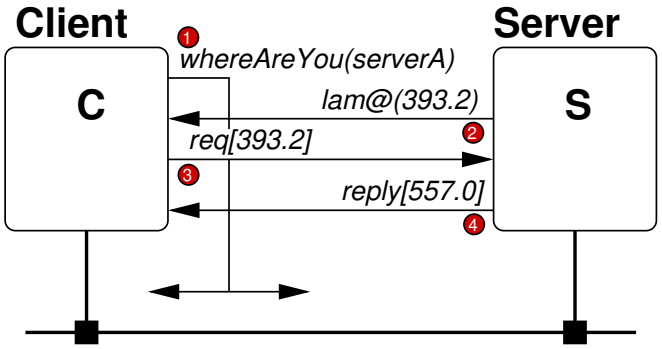
# Agenda

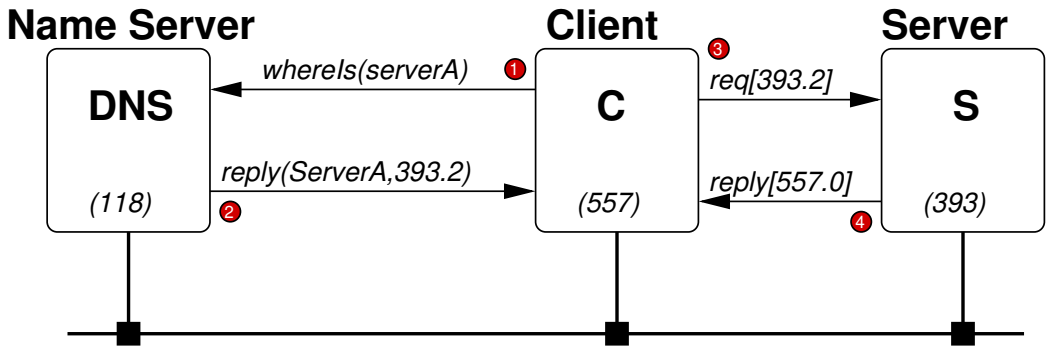
# Name Services

- **Name resolution:**
  - Process to find the address property for a given name of an object
- **Name service**:
  - Provides name resolution for requesting clients
  - For RPC systems it is also called binder
  - Typical operations:
    - Register/Bind
    - Deregister/Unbind
    - Resolve/Lookup

# Types of Name Resolution

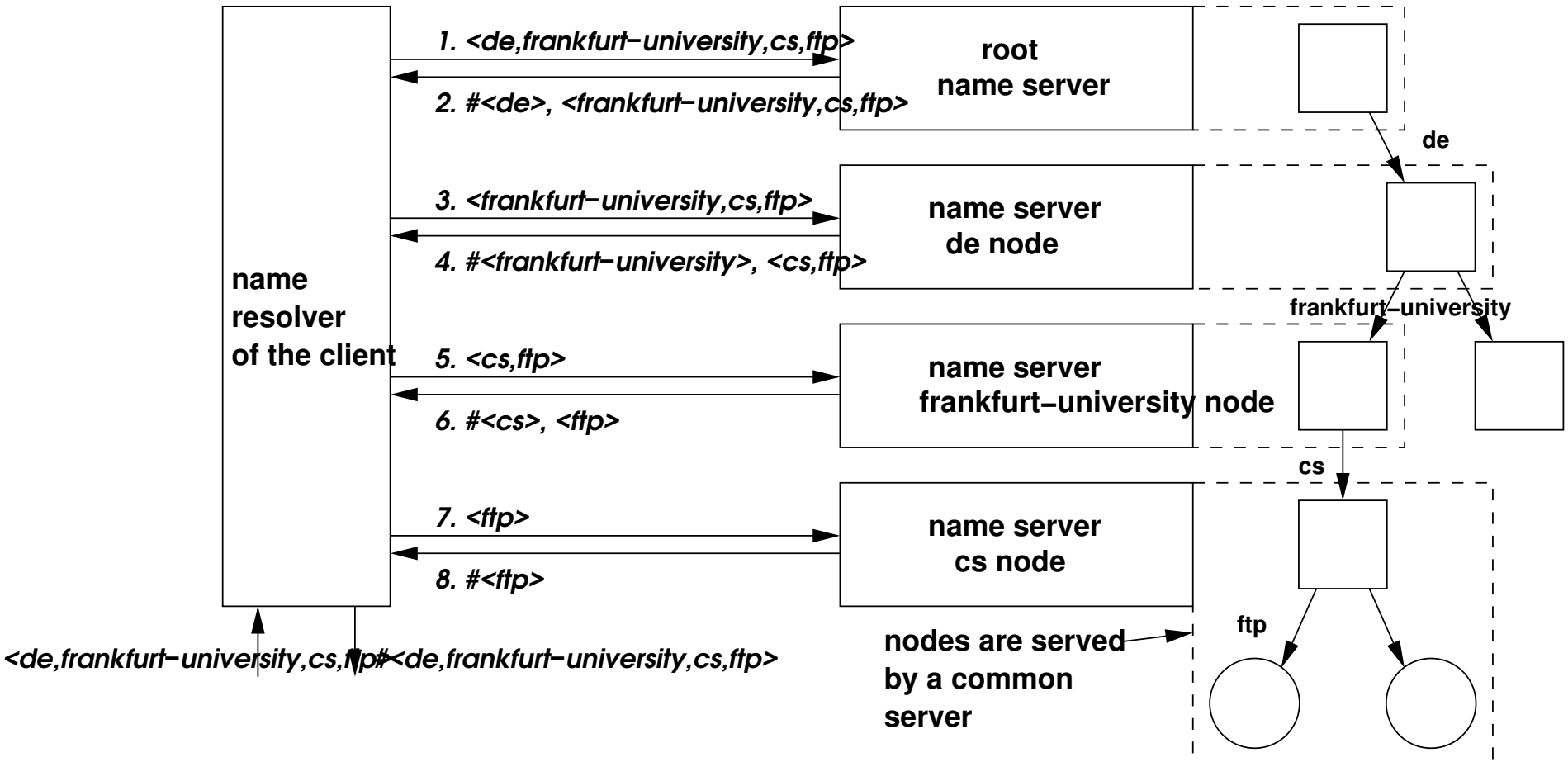
- Search via broadcast
  - Request is sent to everyone and only the node which can resolve the name responds
  - Drawback: Does not scale
  - Example: ARP → Resolution of IP addresses to MAC addresses
- Via name server
  - Requests are sent to a dedicated server which maintains a mapping
  - Drawback: Requires a well-known address
  - Example: DNS



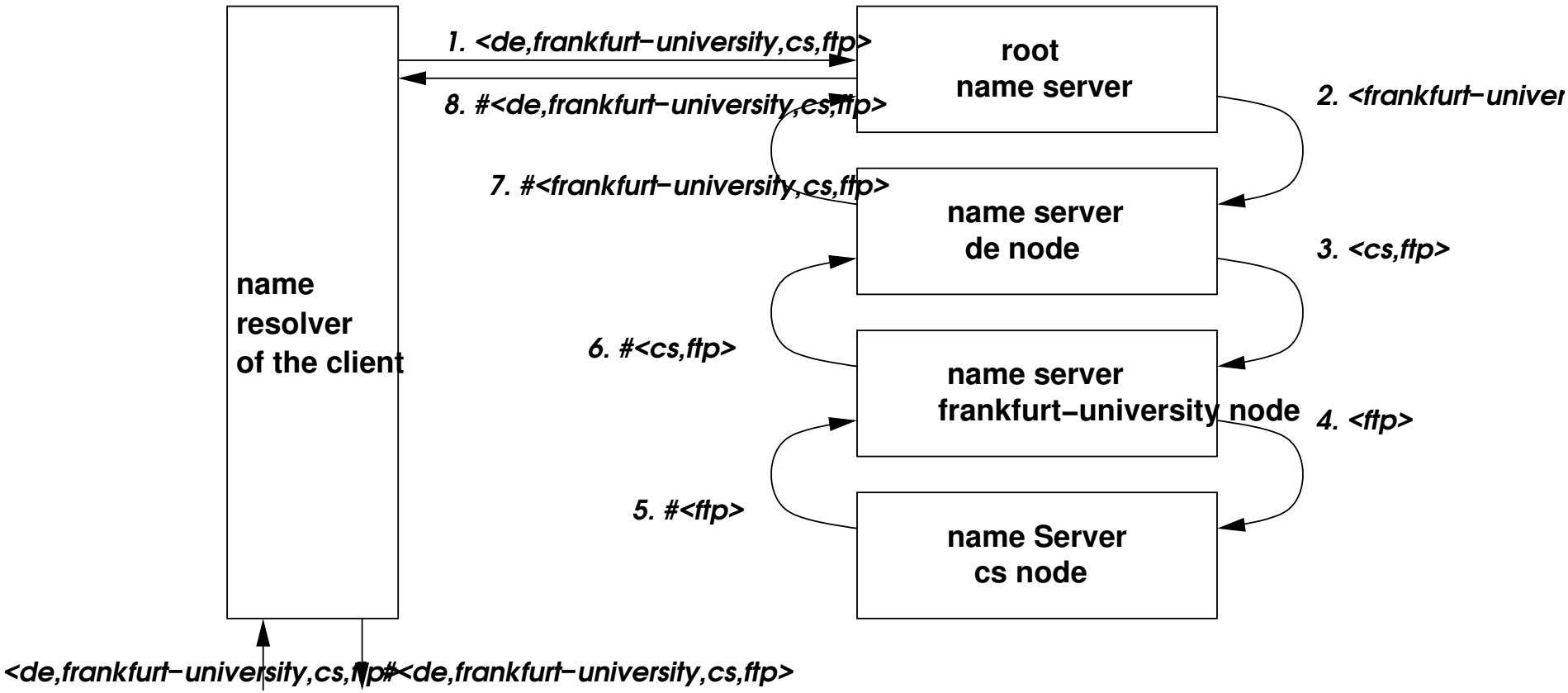
# Iterative Name Resolution

- Starting at the client
- Caching only on client



# Recursive Name Resolution

- Caching on server is possible
- Less traffic
- More load for the root servers



# Common Name Services

- DNS (Internet Domain Name Service)
  - → Lecture Computer Networks
- JNDI (Java Naming and Directory Interface)
- Java RMI Registry
- CORBA INS (Interoperable Naming Service)
  - URLs as names for CORBA objects

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# Agenda

# Directory Services

- Difference to name service:
  - Extension
  - Analogy: **yellow pages** vs. phone book
  - Entries in a directory service are mainly searched by their properties – not by their name
- Standards
  - **X.500** (ITU-T)
    - Complex, used ISO/OSI stack and Directory Access Protocol (DAP)
  - **LDAP** (Lightweight Directory Access Protocol)
    - Implements only a part of the X.500 standard
    - Builds up on top of TCP/IP
    - LDAP = Lightweight version of DAP
    - Typically LDAP does not only refer to the access protocol but to the directory server (LDAP server) itself

# LDAP (Protocol)

- Current version 3 is specified in RFC 4511
- Support by many operating systems
- LDAP server support replication and delegation (referral)
- LDAPv3 supports TLS, SASL, and Kerberos authentication
- Most LDAP data are strings (simple encoding for network transmission), but binary data can be processed as well

# LDAP (Directory)

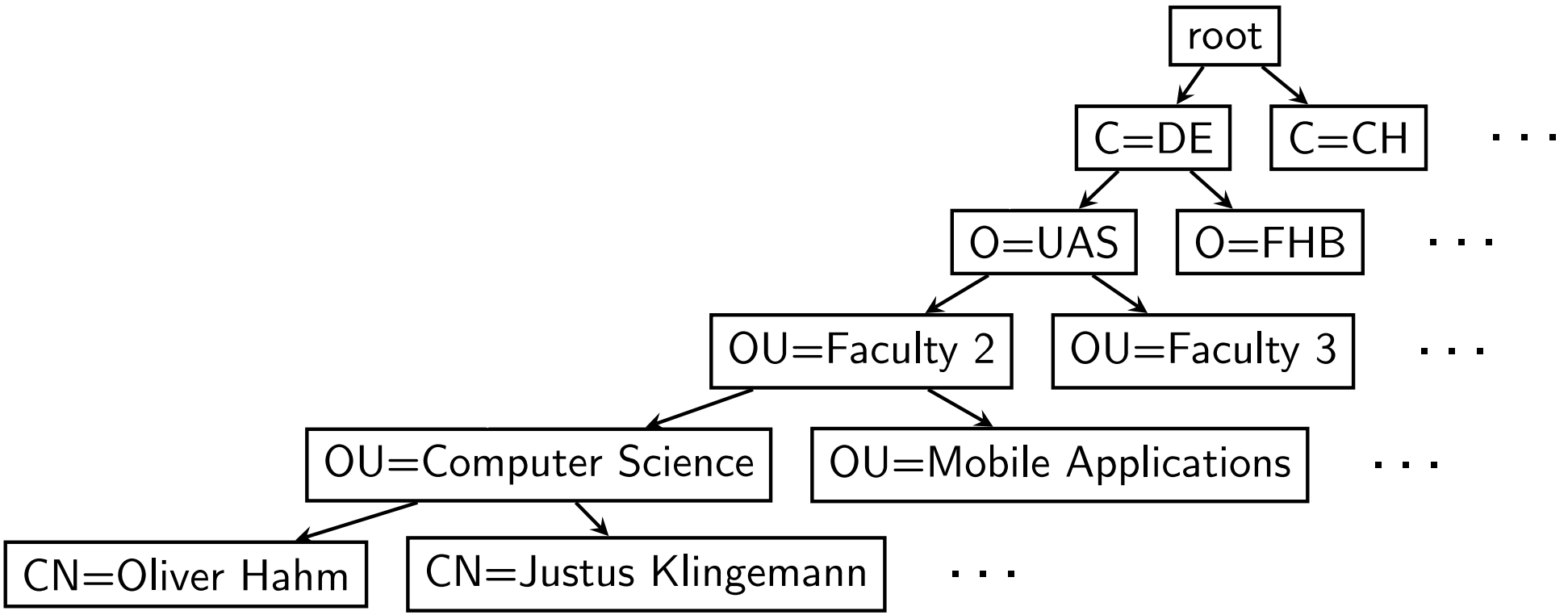
- Hierarchical name space: **Directory Information Tree (DIT)**
- Entries (the nodes of the tree) can be any LDAP objects
- LDAP objects consist of a set of `<attribute, value>` pairs
- **Classes** define object types with particular attribute and value sets
- Each object belongs to at least one class
- Schemata for predefined classes (e.g., person, organization) exist
- Inheritance is possible
- Application specific extensions are possible

# Example

| Attribute | Abbreviation | Value |
|---|---|---|
| Country | C | DE |
| Locality | L | Frankfurt |
| Organization | O | UAS |
| OrganizationalUnit | OU | Faculty 2 |
| OrganizationalUnit | OU | Computer Science |
| CommonName | CN | Oliver Hahm |

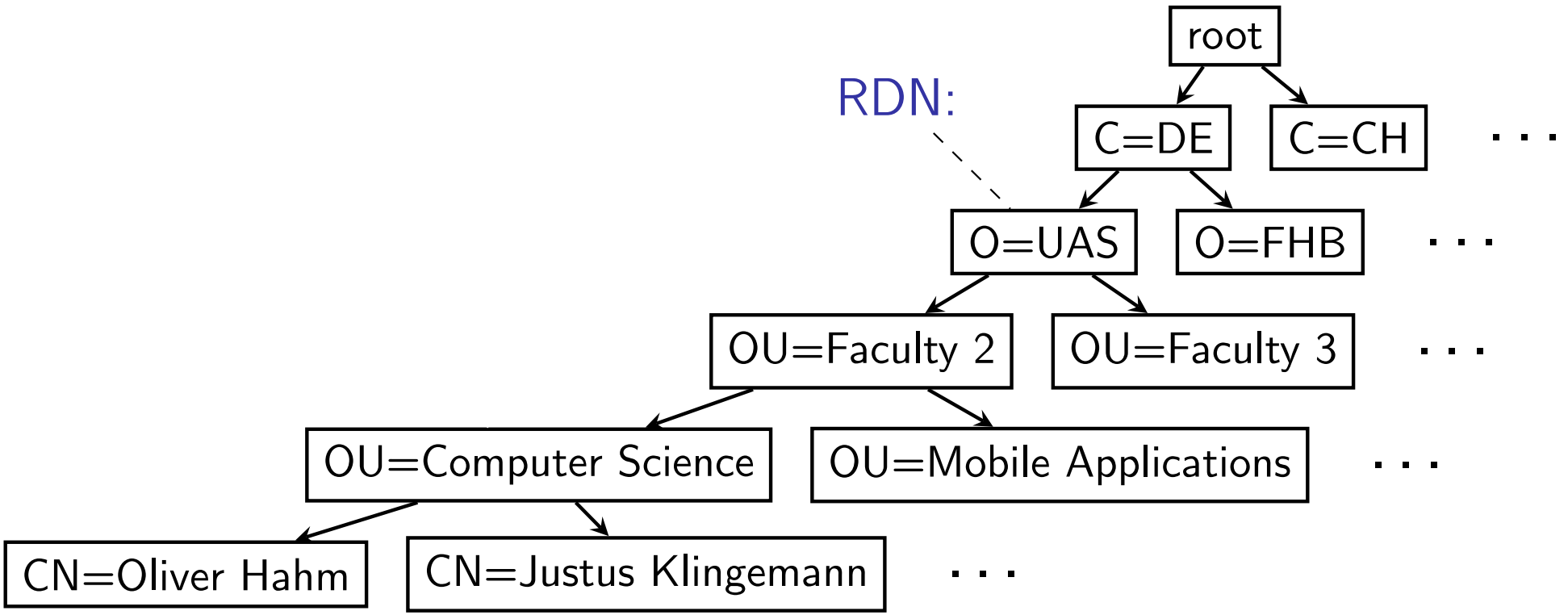
# RDN and DN

- Starting point: DIT root → Base Object



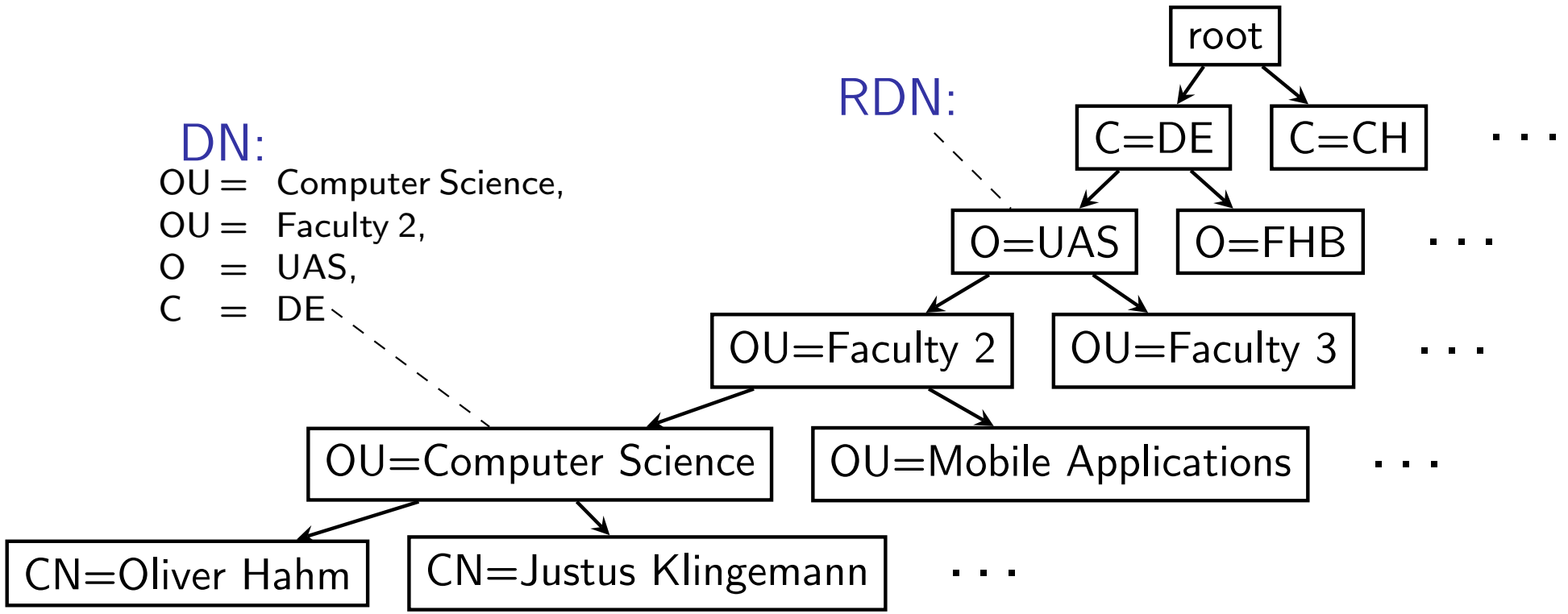
# RDN and DN

- Starting point: DIT root → Base Object
- Each note has a unique name in its layer, called **Relative Distinguished Name (RDN)**



# RDN and DN

- Starting point: DIT root → Base Object
- Each note has a unique name in its layer, called **Relative Distinguished Name (RDN)**
- Concatenation of RDNs from the node towards the root is called **Distinguished Name (DN)** (→ path names)



# Operations

- Bind — Authentication
- Add — Adding an entry
- Delete — Remove an entry
- Search — Search an entry
- Compare — Compare LDAP objects
- Modify — Modify a LDAP object
- ModifyRDN — Move or rename an object
- Abandon — Cancel a running operation
- Unbind — Logout of a client

# Requests

- Usage as name service
  - Find an object by its given Distinguished Name
  - e.g., `read(/C=DE/O=UAS/OU=Computer Science/CN=Oliver Hahm)`, for access to all attributes of the object
- Search objects with certain attributes
  - Request can return a list of results
- Requests may be complex:
  - Wildcards, regular expressions, e.g., &(C=DE)(CN=*Hahm)

# Replication

- Parts of the name space are typically replicated on multiple servers
  - In order to improve **fault tolerance** and **performance**
  - Especially central parts
  - Replication may take hours
  - **Primary-Replica** [1] configuration
    - Modifications happen only at the primary
    - Propagation to replicas
- **Problem:** Duration for updates upon modifications
  - Updates are not immediately visible globally
  - Can only be tolerated, if ...
    - Big read/write relation
    - Reading of outdated entries is uncritical

[1] In older literature called **Master-Slave** configuration

# Applications

- **User/identity management**
  - Scheme: inetOrgPerson (RFC 2798)
- **Address books** of mail systems
  - e.g., Thunderbird interface to LDAP
- **Company organization**
  - Information according to organigrams
- **Inventory system** or infrastructure management

# LDAP/X.500 Products

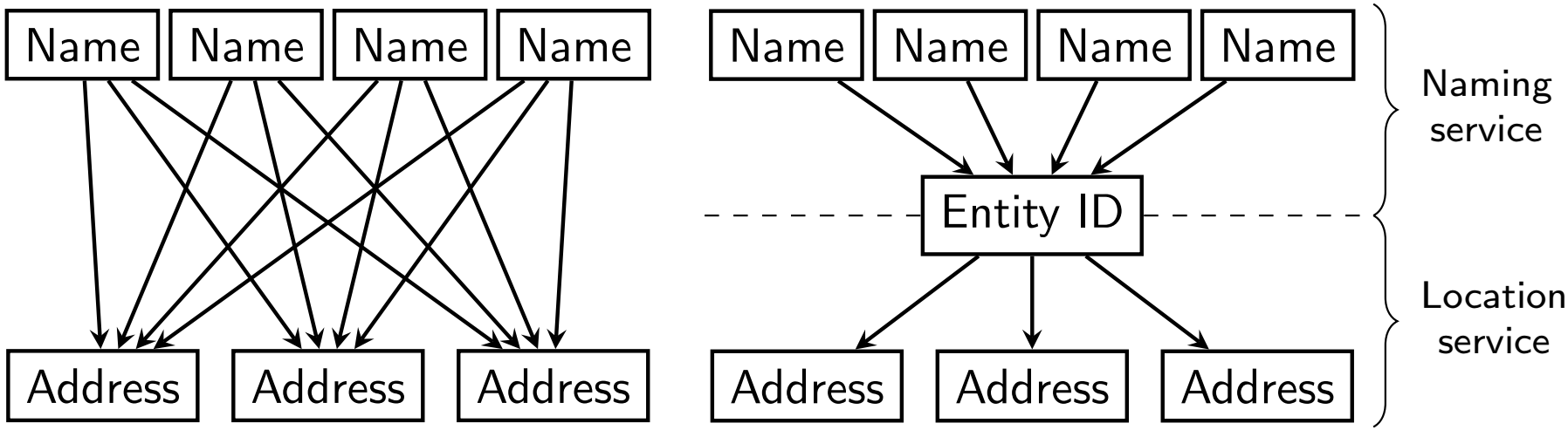
- OpenLDAP (Open Source)
- NetIQ eDirectory (formerly Novell eDirectory, before that Novell Directory Services NDS)
- MS Active Directory (with LDAP Interface)
- Atos DirX (formerly Siemens DirX)
- Oracle Directory Server (formerly Sun Directory Server)

# Agenda

# Location Services

- **Problems** arise when objects may **change their** (phyiscal) **address quickly**
  - Each time the name server entries must be changed ⇒ problem with replication and caching
- **Solution:**
  - Split into **naming** and **location service**
  - Mapping: Name → unique entity ID → location

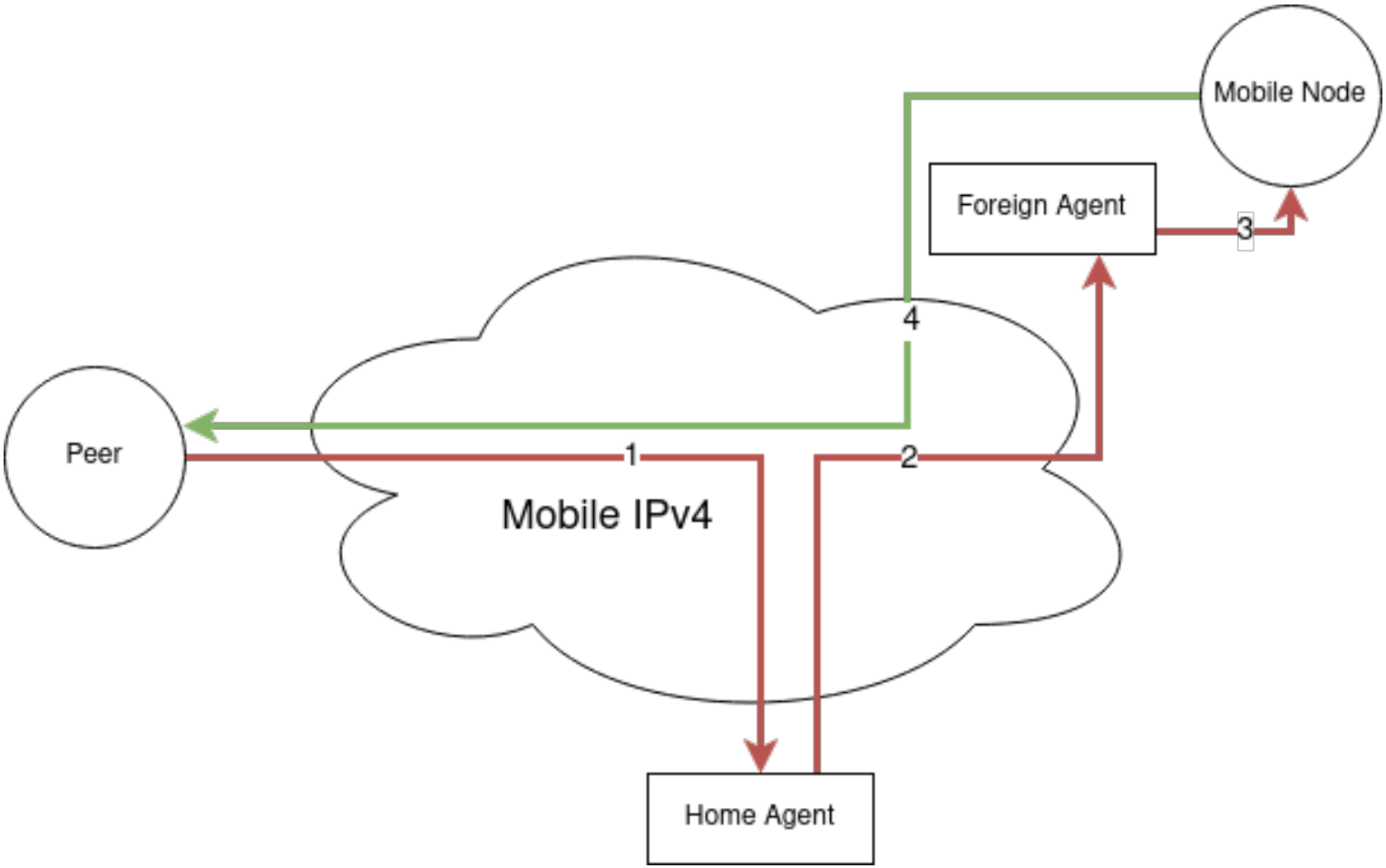
  ⇒ Only one update required



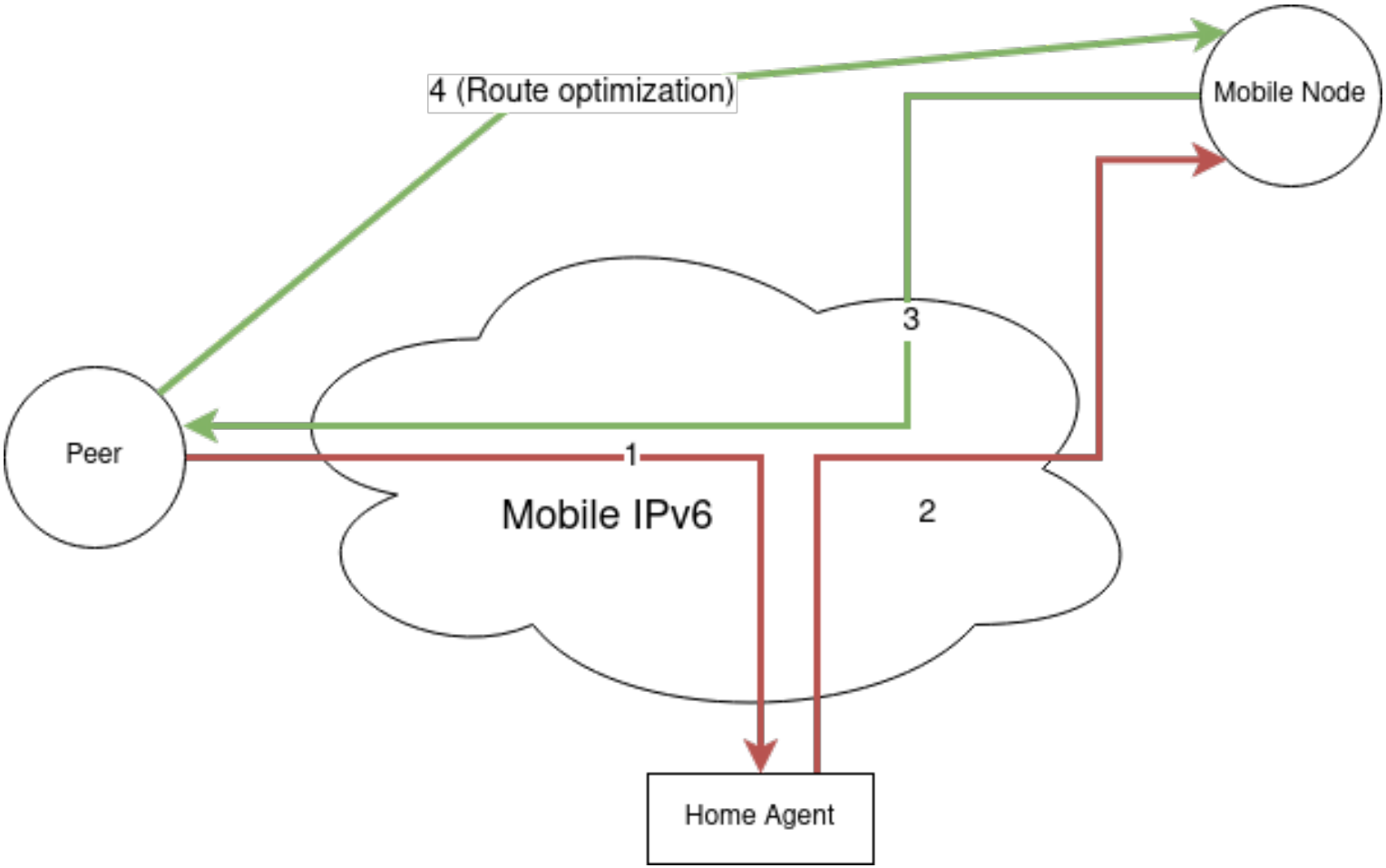
# Identifier-Locator Split

- Each participant requires two **designators** (addresses)
  - An **identifier (ID)** specifies **who** it is
  - A **locator (Loc)** specifies **where** it is
- In static networks both designators are static:
  - $\Rightarrow$ Can be reduced to one address
  - In the Internet the IP address represents ID and Loc
- In **mobile networks** the locator changes
  - ID and Loc diverge $\rightarrow$ **ID-Loc split**
  - Network and end systems have to handle this duality

# Mobile IPv4



# Mobile IPv6


4 (Route optimization)
Mobile Node
3
Peer
1
Mobile IPv6
2
Home Agent

Important takeaway messages of this chapter

- Names can be unique and pure/impure
- Their name is only meaningful for a particular context
- Name services can be used for name resolution (name $\rightarrow$ address)
- Directory services extend this approach and allow for searching by further attributes