Introduction to LDAP

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Carnet User Conference,

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Directory in German Research environment

- Since 1994 DFN research projects at University of Tübingen:
  - AMBIX - an Email directory
  - DFN Directory Services (DDS)
    - Directory competence center
- Since January 2001: DAASI International GmbH
  - Directory Applications for Advanced Security and Information Management
  - Design, implementation and management of directory services
  - Main Customers: Research Institutions in Europe (NRNs, Universities, etc.)

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Agenda

- What is a Directory
- What is X.500
  - History
  - Information model
  - Client server model
- What is LDAP
  - History
  - Concepts
  - Information model

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Agenda (contd.)

  - Functional model
  - Extensions
  - Replication
  - Access Control
  - New developments
- What can you do with it?
  - Indexing
  - PKI
- LDAP and Grid computing

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What is a Directory?

A short introduction

What is a Directory?

- Information stored in a hierarchical System
- Examples:
  - File directory of an operating system (MS/DOS, Unix)
  - Domain Name Service (DNS)
  - Network Information System (NIS)
  - X.500 is *the* Directory
  - Lightweight Directory Access Protocol (LDAP)
  - Novell Directory Service (NDS)
  - Microsoft Active Directory (AD)

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So what really is *the* Directory

- It is a sort of a database
  - for storing and retrieving information
- It is a specialized database
  - designed for fast reading, writing is slower
  - static view on the data
  - simple updates without transactions
- It has a network protocol for access
- A Directory Service may include
  - distribution in the net
  - replication of the data

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What kind of data can you store?

- Text data
  - names, addresses, descriptions, numbers, etc.
- Pointers
  - URLs, pointers to other data, etc.
- Public key certificates
- Graphics
  - photos, diagrams, etc.
- Other binary data
- Anything else you can think of

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What is X.500?

Some of these slides are for meant reading and are more of historical interest. ○

Some are basics for LDAP

X.500

- Standard of ITU / ISO
- Part of OSI (Open Systems Interconnection)
  - backdraws:
    - theoretical
    - complex
    - little acceptance
  - advantages:
    - conforming to OSI
    - good concept
    - modern design

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Standardization boards

- ISO
  - International Standards Organization
  - Name of the Directory standard: ISO 9594
- CCITT
  - Comitée Consultative International Telephonique et Telegraphique
  - The former international board for Telecommunication Organizations
  - Name of the same standard: X.500
- ITU
  - International Telecommunications Union
  - The successor of CCITT

History of the X.500 standard

- 1984 start of efforts for defining a standard for distributed data in the net
- 1988 first version of the standard (X.500v1)
  - X.509 includes authentication based on asymmetric encryption
  - Undefined access control and replication
  - proprietary replication mechanism in first implementation Quipu from the ISODE Consortium
- 1993 second version (X.500v2)
  - includes the missing bits:
    - Replication called shadowing
    - access control

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History contd.

- 1997 third version (X.500v3)
  - includes enhanced definitions for certificates in X.509v3: Extensions
- 2001 fourth version (X.500v4)
  - X.509v4 adds Attribute Certificate and Privilege Management Infrastructure

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Parts of the X.500 Standard

- X.500 - Overview of concepts, models and services
- X.501 - Models
- X.509 - Authentication framework
- X.511 - Abstract service definition
- X.518 - Procedures for distributed operation
- X.519 - Protocol specifications
- X.520 - Selected attribute types
- X.521 - Selected object classes
- X.525 - Replication
- X.530 - Use of system management for administration of the Directory

History of X.500: Projects

- 1989: NYSERNet White Pages Pilot Project
  - US initiative with participation of 90 organisations in 12 countries
- 1992: North American Directory Forum (NADF)
  - important US project
  - Specifications of directory service
- 1991: Piloting A ResArchers Directory Service in Europe (Paradise)
- 1993: DANTE takes over: NameFLOW-Paradise

What was X.500 intended for?

- To give humans information like
  - Data (Telephonenumbers etc.) about humans (White Pages)
  - Data (postal address etc.) about organisations (Yellow Pages)
- To give applications data in a known format for
  - Message handling
  - File transfer (File Transfer Access Management, FTAM)
  - Name mapping for OSI
- The Standard defines a set of data fields for these purposes

Qualities of X.500

- Any amount of data can be stored
- On any number of servers
- Clients need to connect to only one server
- Data look the same everywhere
- Open model for any kind of data

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X.500 Information Tree

- Data are stored in entries
- Entries are ordered as tree nodes
- In the Directory Information Tree (DIT)
  - Every node has 0 to n children nodes
  - Every node except root has 1 parent node

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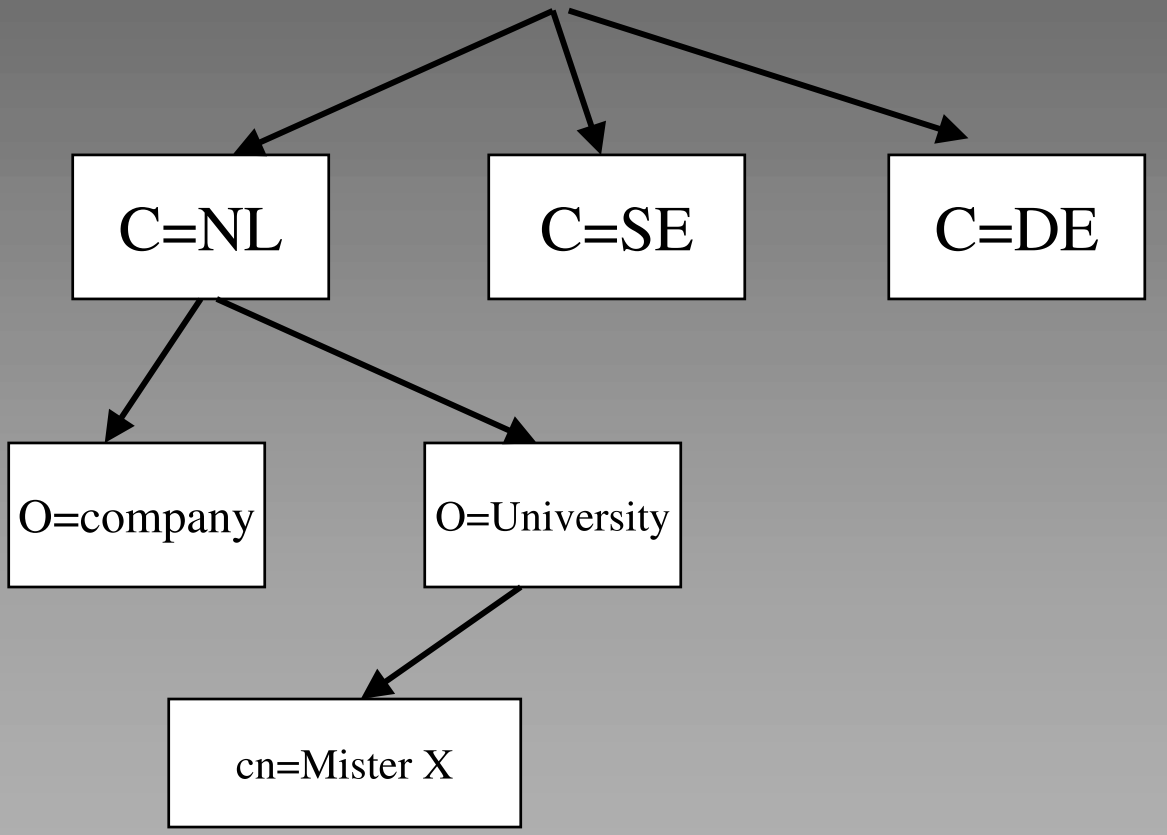
Directory Information Tree (DIT)


C=NL

C=SE

C=DE

O=company

O=University

cn=Mister X

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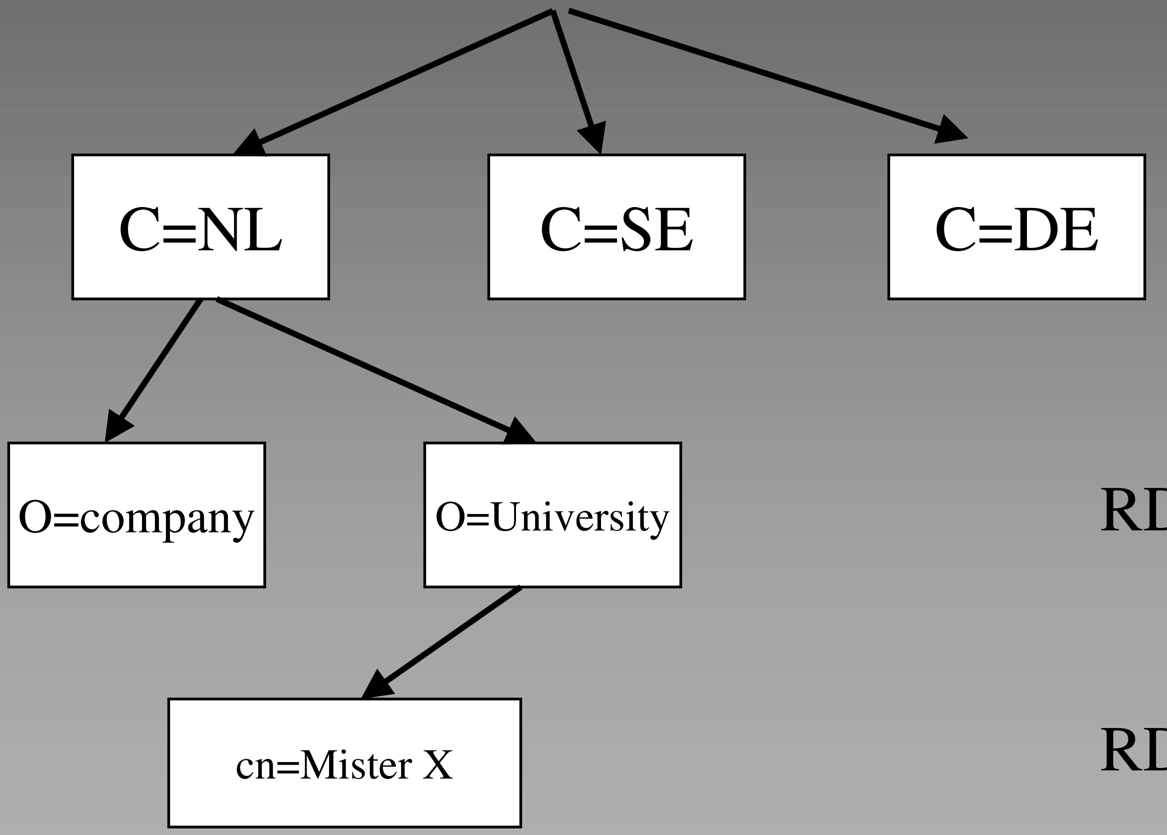
DN Distinguished Name

- An entry has a distinguished name
  - in its hierarchy level: Relative Distinguished Name (RDN)
  - all RDNs on the path from root form the Distinguished Name (DN)
- No two siblings, i.e. entries with a common parent can have the same RDN
- Thus no two entries in the whole Directory can have the same DN

Relative Distinguished Name (RDN) and Distinguished Name (DN)



C=NL

C=SE

C=DE

O=company

O=University

cn=Mister X

RDN: C=NL

RDN: o=University

RDN: cn=Mister X

DN: c=NL;o=University;cn=Mister X

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DN Pointer

- Alias Entries have a DN and point to another DN via aliasObjectName Attribute
- seeAlso Attribute: Entry contains data and a seeAlso pointer to another DN

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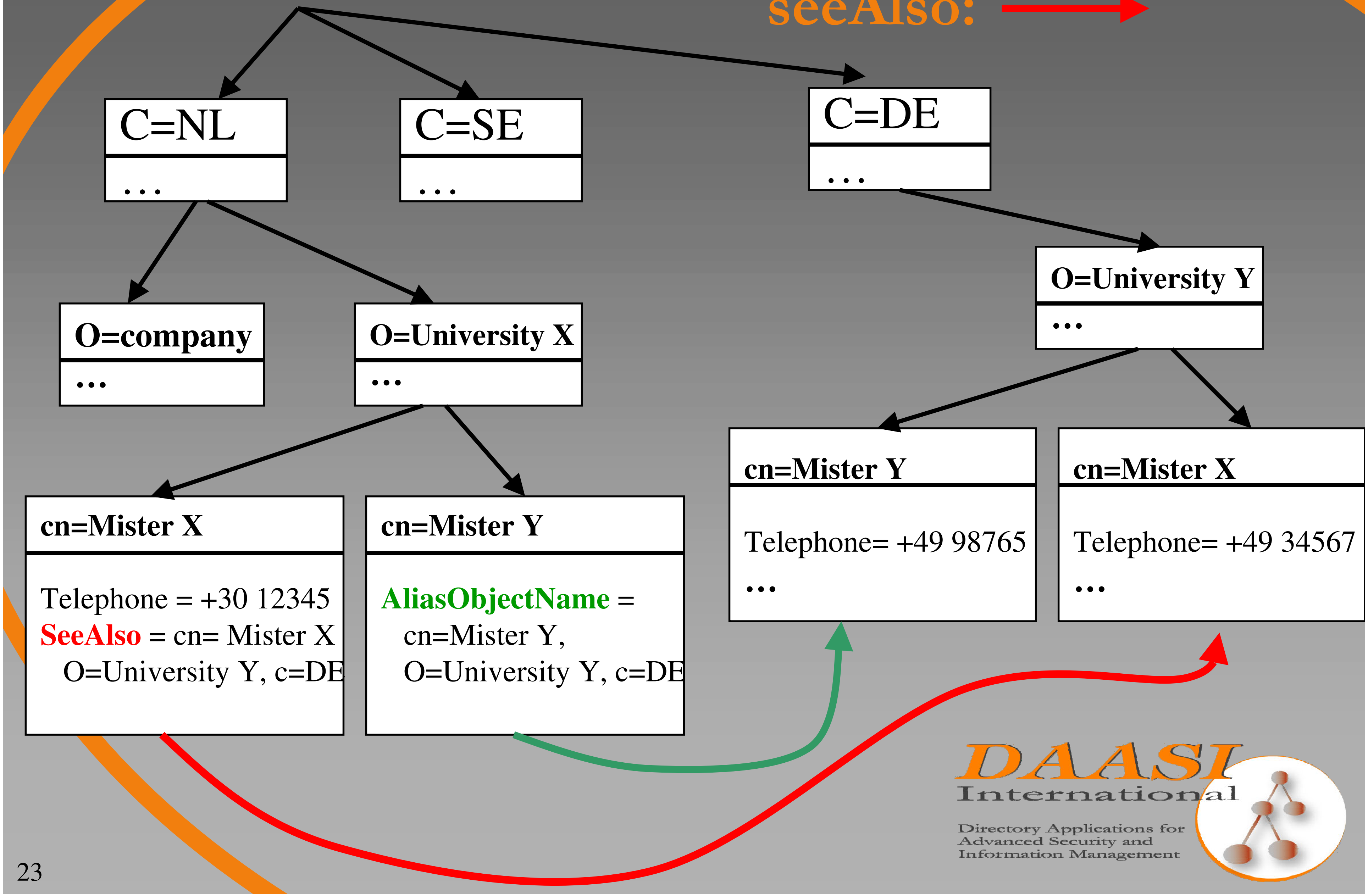
AliasObjectName: →

seeAlso: →



C=NL
…

C=SE
…

C=DE
…

O=company
…

O=University X
…

O=University Y
…

cn=Mister X

Telephone = +30 12345
SeeAlso = cn= Mister X
O=University Y, c=DE

cn=Mister Y

AliasObjectName =
cn=Mister Y,
O=University Y, c=DE

cn=Mister Y

Telephone= +49 98765
…

cn=Mister X

Telephone= +49 34567
…

How is the information stored?

- An Entry is an information object
- The mechanisms for representing and describing the data (e.g. value syntax) are objects as well, identified by an OID (Object Identifier)
- OIDs are again represented in an hierarchical tree

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OID-Tree

- E.g.: Subtree maintained by DAASI International:
  - Daasi = 1.3.6.1.4.1.10126
  - For more see: http://www.alvestrand.no/objectid/
  - On 1.3.6.1.4.1. See also http://www.iana.org/assignments/enterprise-numbers
  - By now 13865 Enterprise-numbers have been assigned

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X.500 Information Model

- An Entry contains a number of Attributes
- An Attribute consists of:
  - Attribute Type
  - Attribute Value(s)
- An Attribute Type has an associated Attribute Syntax
- The Attribute Value has to conform to that syntax
- Matching Rules to compare Attribute values for
  - equality
  - substring
  - ordering
  - extensible (selfdefined) matching

Special Attributes

- One or more Attribute type/value pairs form the RDN
  - The Naming Attributes or
  - The Distinguished Attributes
- An Entry must have one or more **Objectclass Attributes** which:
  - Characterizes the Entry, e.g. Person
  - Defines a set of usable Attributes the entry may contain and must contain
- Objectclasses can inherit Attributes from other Objectclasses
- A set of Objectclasses, Attributes and Syntaxes for a special purpose is called schema

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Objectclass inheritance

- One Objectclass can be superclass of another
- The subclass inherites all attribute definitions of the superclass. E.g.:
    - Objectclass person includes attribute surname. Etc.
    - organizationalPerson inherits attributes of person and adds new attributes like RoomNumber, etc.

Objectclass Types 1

- ABSTRACT
  - Only used for the Object class at the root of the inheritance called top

Objectclass Types 2

- STRUCTURAL
  - These describe a whole thing
  - Represent an entity
  - E.g.: Person, Organisation, etc
  - Every entry may only have one structural objectclass (together with it‘s inheritance descendence, e.g. person and organizationalPerson)

Objectclass Types 3

AUXILIARY

- These describe single additional aspects of an entity
- Different kinds of entities can have common aspects
- You can add as many AUX classes to an entry as you want
- E.g.: PKIuser includes the attribute certificate. A person can have a certificate, but a server as well
- Another example: labeledUriObject, with attribute labeledURI.

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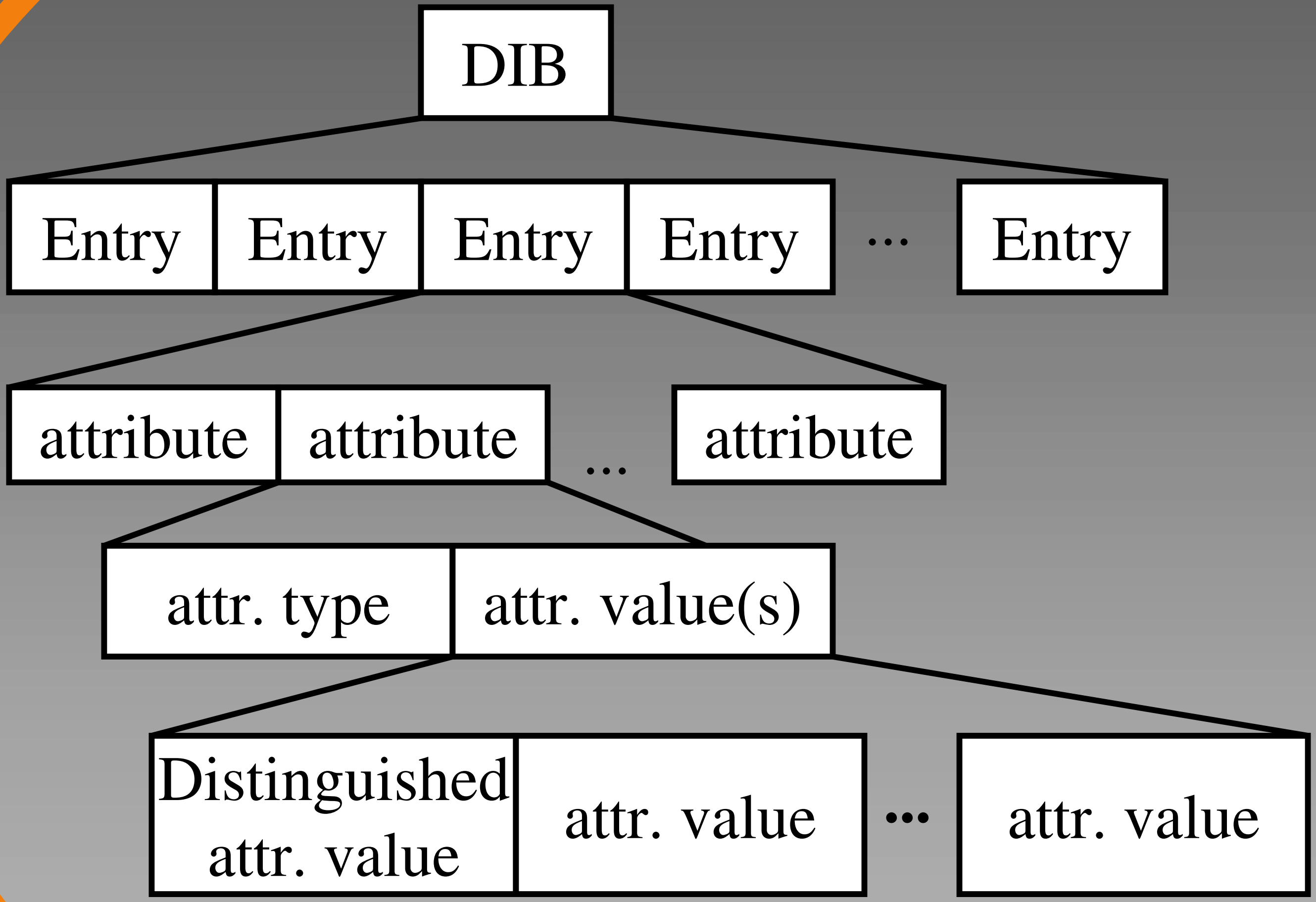
Attribute inheritance

- Attributes can also stand in an inheritance hierarchy
  - E.g.: name -> common name
    -> surname
  - E.g.: telephone number -> home number
    -> office number
- If you request the more general attribute you will get all more specific attributes

Directory Information Base



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Example:

DN: cn=Mister X, o=University, c=NL

Objectclass=top
Objectclass=person
Objectclass=organizationalPerson
cn=Mister X
cn=Xavier Xerxes
mail=X@dot.com
mail=Mister.X@dot.com
telephoneNumber=1234567

Some Objectclasses

ObjectClass	distinguished Attr. and abbreviation	other Attributes
country	countryName or c	description, searchGuide, ...
locality	localityName or l	description, ...
organization	organizationName or o	description, postalAdress, ...
organizational Unit	organizationalUnit -Name or ou	description, postalAdress, ...
person	commonName or cn	surname, title, ...

Open structure

- You can define your own:
  - Object Classes
  - Attribute Types
  - Attribute Syntaxes
  - Matching Rules
- You can locally use self defined schemas
- If you want them to be used globally you have to
  - standardize them (IETF)
  - or at least register them

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X.500 Client Server model

- Directory Service Agent (DSA)
  - A Server that holds directory information
- Directory User Agent (DUA)
  - A client that connects to a DSA to access information
- The DUA and DSA communicate via an access protocol
- The X.500 access protocol is called Directory Access Protocol DAP
- A lightweight version of DAP is LDAP
  Lightweight **D**irectory **A**ccess **P**rotocol

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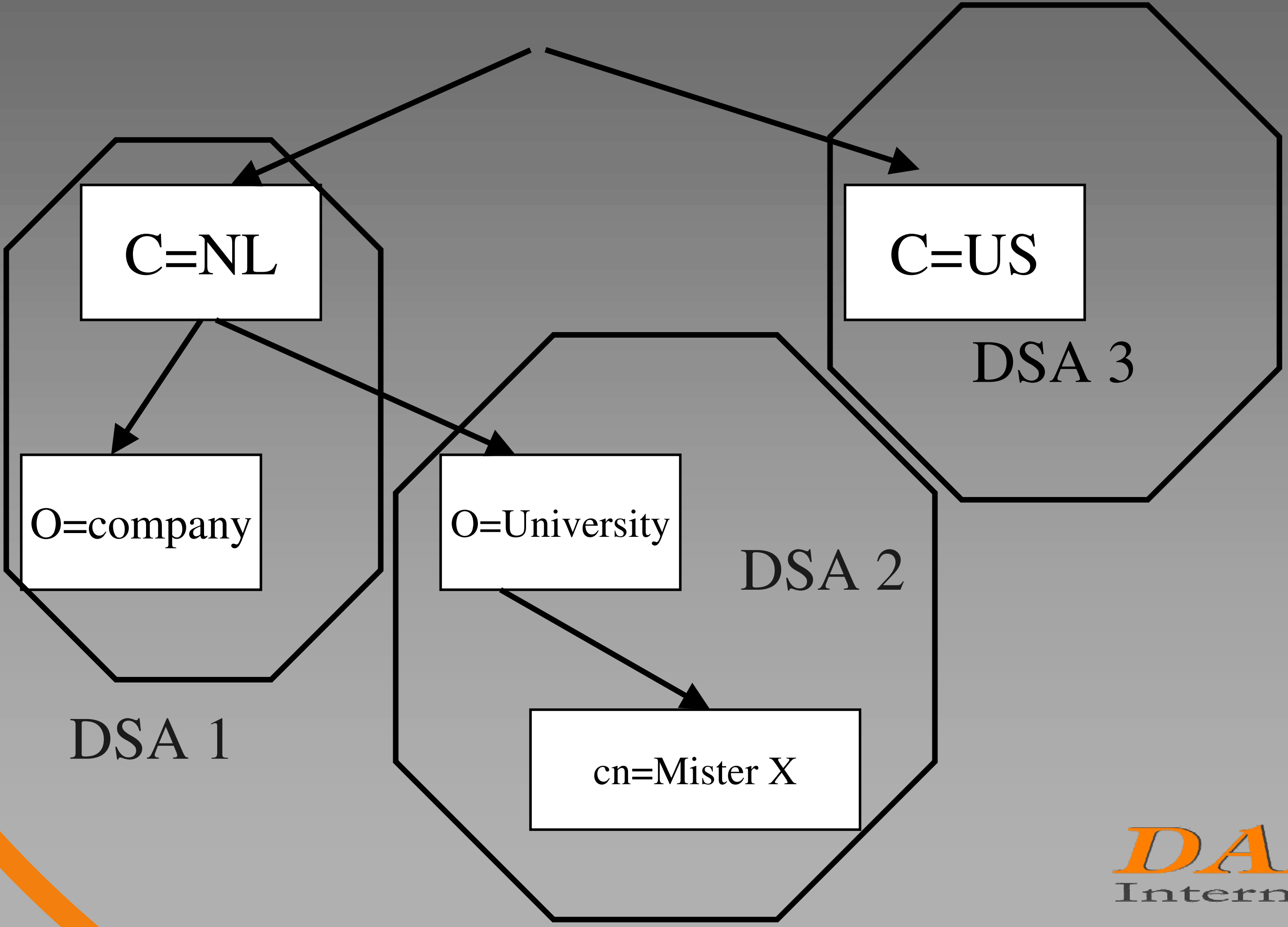
Distribution of the data among DSAs



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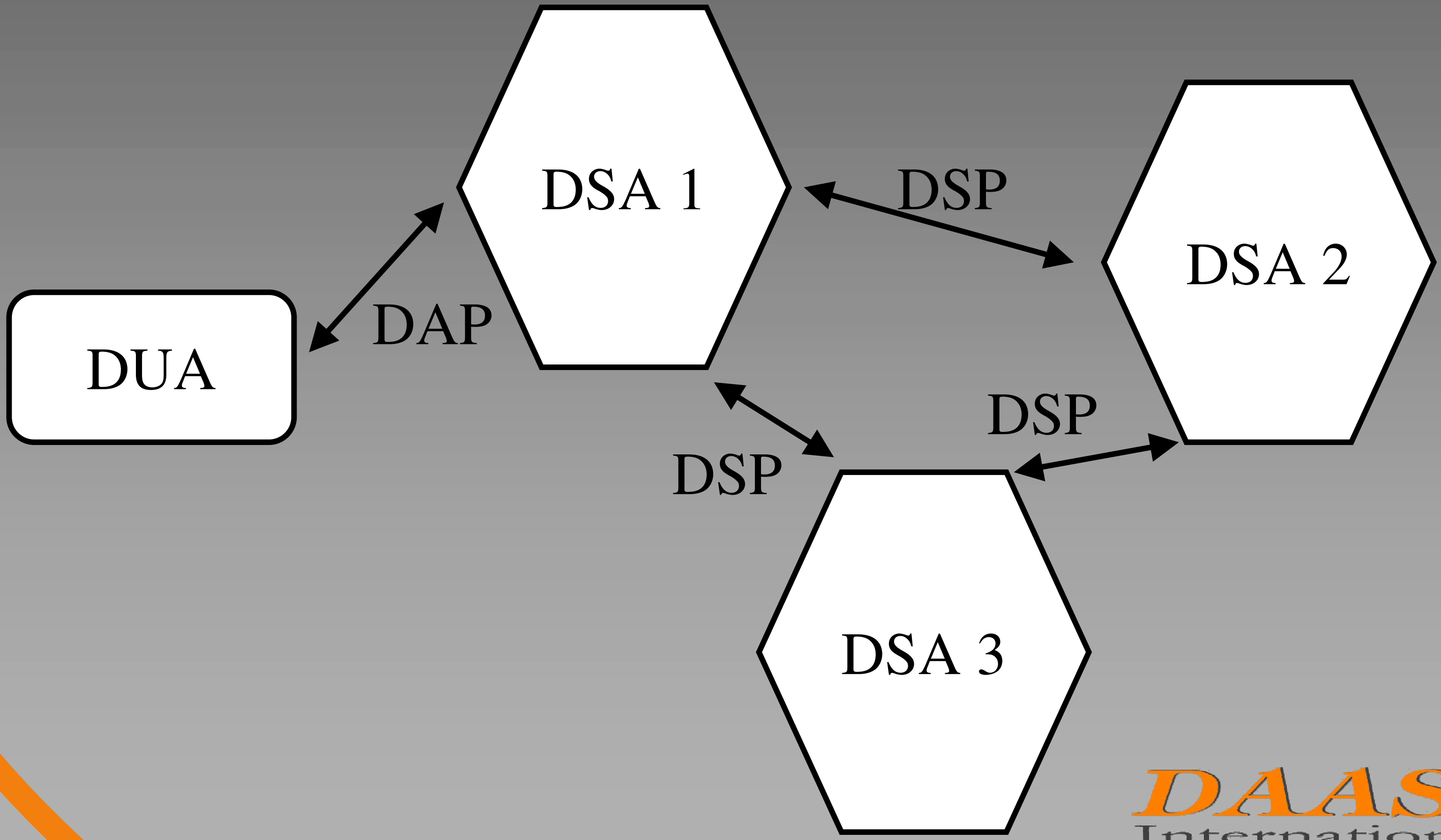
Directory Server Protocols

- Directory System Protocol (DSP)
  - One DSA retrieves data requested by a client from another DSA
- Directory Operational Binding Management Protocol (DOP)
  - Knowledge references between DSAs
  - Hierarchical Operational Binding (HOB)
  - Shadow Operational Binding
- Directory Information Shadowing Protocol (DISP)
  - One DSA replicates data on another DSA
  - Protocol for replication agreements

Directory Server Protocols



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Some more X.500 Features

- All Protocols conform to the OSI Stack
  - 7 protocol layers with interfaces between each other
  - hard to implement
- Attributes can be inherited along the DIT (Collective Attributes)
- Authentication mechanisms
- Access control

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What is LDAP?

About LDAP standardization and differences to X.500

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History of LDAP: LDAP v1

- A group at University of Michigan developed a Lightweight Version of DAP
  - No OSI Stack
  - Directly over TCP
  - Only DUA - DSA communication
  - Most protocol data elements ordinary strings
  - Easier to implement
  - better performance
- First Implementation was called DIXIE
- LDAPv1 was never published as IETF RFC

1993: LDAP v2 Proposed Standard

- RFC 1487:
  - X.500 Lightweight Directory Access Protocol, W. Yeong, T. Howes, S. Hardcastle-Kille. July 1993
- RFC 1488:
  - The X.500 String Representation of Standard Attribute Syntaxes. T. Howes, S. Kille, W. Yeong, & C. Robbins. July 1993
- RFC 1558:
  - A String Representation of LDAP Search Filters. T. Howes. December 1993

1995: LDAP v2
Draft Standard

- RFC 1777:
  - Lightweight Directory Access Protocol, W. Yeong, T. Howes & S. Kille. March 1995
- RFC 1778:
  - The String Representation of Standard Attribute Syntaxes, T. Howes, S. Kille, W. Yeong & C. Robbins. March 1995
- RFC 1798:
  - Connection-less Lightweight Directory Access Protocol, A, Young. July 1995
- RFC 1823:
  - The LDAP Application Program Interface, T. Howes & M. Smith. August 1995

1997: LDAP v3 Proposed Standard

- RFC 2251:
  - Lightweight Directory Access Protocol (v3), M. Wahl, T. Howes, S. Kille. December 1997
- RFC 2252:
  - Lightweight Directory Access Protocol (v3) - Attribute Syntax Definitions, M. Wahl, A. Coulbeck, T. Howes, S. Kille. December 1997
- RFC 2253:
  - Lightweight Directory Access Protocol (v3) - UTF-8 String Representation of Distinguished Names, M. Wahl, S. Kille, T. Howes. December 1997

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1997 LDAPv3 contd.

- RFC 2254:
  - The String Representation of LDAP Search Filters, T. Howes. December 1997
- RFC 2255:
  - The LDAP URL Format, T. Howes, M. Smith. December 1997
- RFC 2256:
  - A Summary of the X.500(96) User Schema for use with LDAPv3, M. Wahl. December 1997

Who talks LDAP?

- Originally (v1,v2) just a client access protocol for X.500
- LDAP v3 is a whole client server system
- All directory implementations have an LDAP interface:
  - all X.500(93) implementations
  - Novell Directory Service (NDS)
  - Microsoft Active Directory (AD)
- Many client applications have an LDAP interface:
  - mailagents
  - browsers
  - PGP clients

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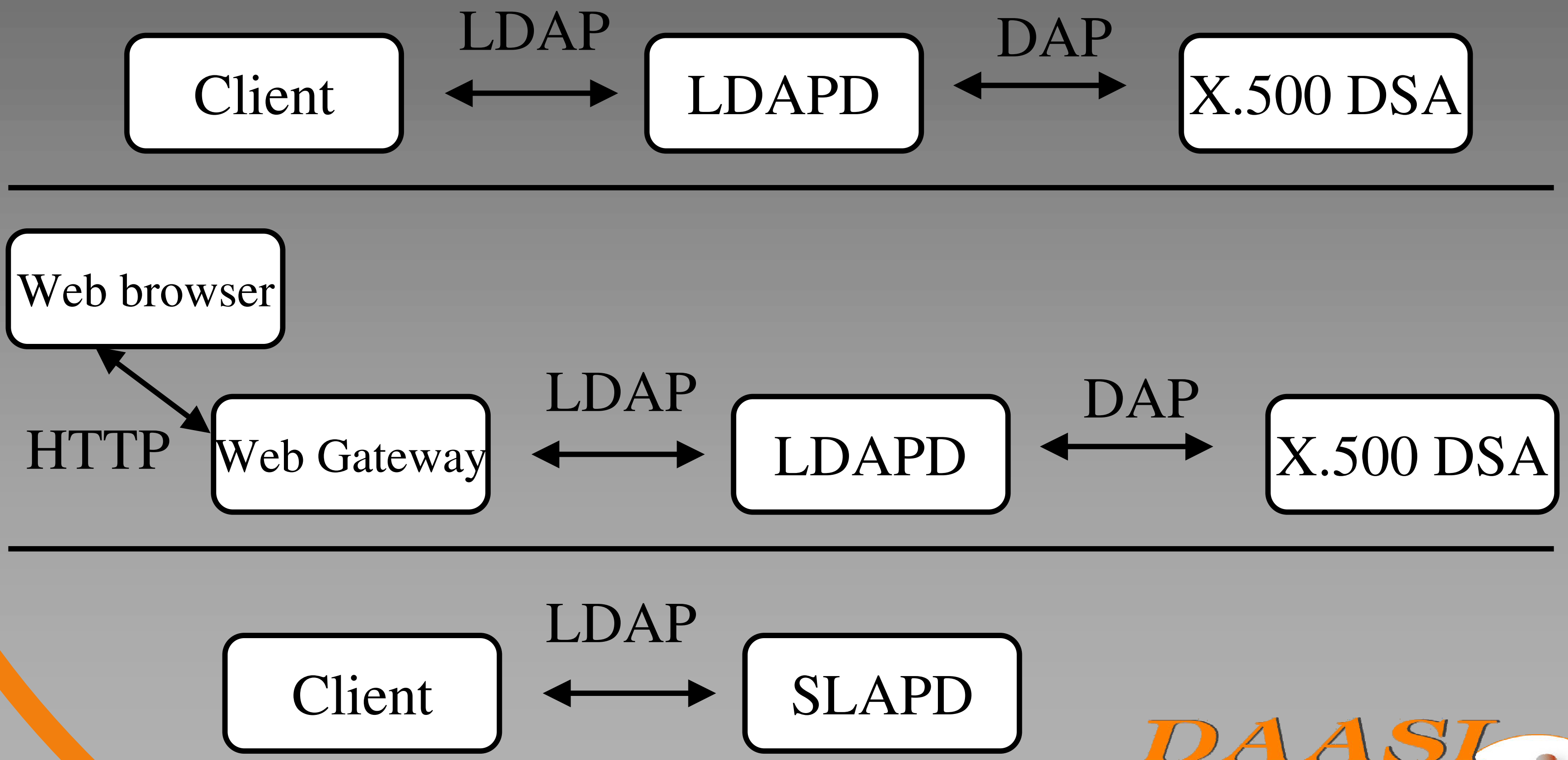
LDAP connectivity



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LDAP Features

- The LDAP standard defines...
  - a network protocol for accessing information in the directory
  - an information model defining the form and character of the information
  - a namespace defining how information is referenced and organized
  - secure authentication mechanisms
  - an emerging distributed operation model defining how data may be distributed and referenced (v3)
  - Both the protocol itself and the information model are extensible
  - A C API and a Java API

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Open Source Implementation

- OpenLDAP
  - Current versions 2.x.x are LDAPv3 compliant
  - Lots of important features like TLS, SASL
  - Code well maintained by Kurt Zeilenga and a core developers team
  - Used in large scale production environment
  - Not very slow
  - See www.openldap.org

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LDAP Information Model

- Just like X.500
  - Entry
  - Attribute Type
  - Attribute Syntax
  - Attribute Value
  - Matching Rule
  - Object classes
- Different:
  - String representation of the values
  - Attribute Description is AttributeType plus option separated by ´;´ also called tag. E.g. userCertificate;binary

Attribute definition (RFC2252)

```
AttributeTypeDescription = "(" whsp numericoid whsp ;
    AttributeType identifier
    [ "NAME" qdescrs ] ; name used in AttributeType
    [ "DESC" qdstring ] ; description
    [ "OBSOLETE" whsp ]
    [ "SUP" woid ] ; derived from this other AttributeType
    [ "EQUALITY" woid ; Matching Rule name
    [ "ORDERING" woid ; Matching Rule name
    [ "SUBSTR" woid ] ; Matching Rule name
    [ "SYNTAX" whsp noidlen whsp ] ; -> sect. 4.3
    [ "SINGLE-VALUE" whsp ] ; default multi-valued
    [ "COLLECTIVE" whsp ] ; default not collective
    [ "NO-USER-MODIFICATION" whsp ]; default user
    modifiable
    [ "USAGE" whsp AttributeUsage ];
                    default userApplications whsp ")"
```

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Attribute definition contd.

AttributeUsage =
"userApplications" /
"directoryOperation" /
"distributedOperation" / ; DSA-shared
"dSAOperation" ; DSA-specific, value depends on
server

Attribute definition contd.

oid = descr / numericoid

descr = keystring

numericoid = numericstring *(". " numericstring)

woid = whsp oid whsp ; set of oids of either form

oids = woid / ("(" oidlist ")")

oidlist = woid *("$" woid) ; object descriptors used as schema element names

qdescrs = qdescr / (whsp "(" qdescrlist ")" whsp)

qdescrlist = [qdescr *(qdescr)]

Attributdefinition example

```
( 2.5.18.2
NAME 'modifyTimestamp'
EQUALITY generalizedTimeMatch
ORDERING generalizedTimeOrderingMatch
SYNTAX 1.3.6.1.4.1.1466.115.121.1.24
SINGLE-VALUE
NO-USER-MODIFICATION
USAGE directoryOperation )
```

[Generalized Time Y
1.3.6.1.4.1.1466.115.121.1.24]

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Objectclass definition

```
ObjectClassDescription =
"(" whsp numericoid whsp ; ObjectClass identifier
[ "NAME" qdescrs ]
[ "DESC" qdstring ]
[ "OBSOLETE" whsp ]
[ "SUP" oids ] ; Superior ObjectClasses
[ ( "ABSTRACT" / "STRUCTURAL" / "AUXILIARY" )
            whsp ] ; default structural
[ "MUST" oids ] ; AttributeTypes
[ "MAY" oids ] ; AttributeTypes whsp ")"
```

OC Definition examples

- (2.5.6.0 NAME 'top' ABSTRACT MUST objectClass)
- (2.5.6.6 NAME 'person' SUP top STRUCTURAL MUST (sn $ cn) MAY (userPassword $ telephoneNumber $ seeAlso $ description))

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OC Definition examples

```
( 2.5.6.7 NAME 'organizationalPerson'
SUP person STRUCTURAL
MAY ( title $ x121Address $ registeredAddress $
destinationIndicator $ preferredDeliveryMethod $
telexNumber $ teletexTerminalIdentifier $
telephoneNumber $ internationaliSDNNumber $
facsimileTelephoneNumber $ street $
postOfficeBox $ postalCode $ postalAddress $
physicalDeliveryOfficeName $ ou $ st $ l )
)
```

Standardized Schema

- Schema allready standardized in the core specifications see RFC 2256

Schema definition in Open-LDAP

- Schema definition files can be included by a linen in slapd.conf, e.g.:
  - Include /etc/openldap/schema/core.schema
- Schema definition files contain RFC 2252 like attribute and objectclass definitions described above
  - One difference:
    add „attributetype “ or „objectclass “ before the round bracket

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LDAP Naming Model

- Just like X.500:
  - RDN and DN
  - DIT
  - Alias and seeAlso
- Differences:
  - String representation of DNs
  - Alternative to X.520 naming: Domain componant (DC)
    - X.520: cn=Mister X, o=University, c=NL
    - DC: uid=Misterx1, dc=Uni, dc=NL
    - advantage: registration problems are handled by DNS
  - There is no single international DIT

LDAP Functional Model

- Authentication and control operations:
  - bind
  - unbind
  - abandon
- Interrogation operations:
  - search
  - compare
- Update operations:
  - add
  - delete
  - modify
  - modifyDN

LDAP Search Parameters

1. base object or base DN
    - where in the DIT the search starts
2. scope
    - base (read the entry specified by the base dn)
    - onelevel (search only in the hierarchical level of the basedn)
    - subtree (search in level of base DN and below)
3. derefAliases
    - neverDerefAlias (do not dereference aliases in searching or in locating base object)
    - derefInSearching (dereference only in subordinates of base object)
    - derefFindingBaseObject (dereference only in locating the base object)
    - derefAlways (dereference aliases in searching subordinates and in locationg base object)

LDAP Search Parameters contd.

4. size limit
   - limit the number of entries to get back
5. time limit
   - limit the time the server should spend to fulfil the request
6. attrsOnly
   - Boolean. If set to true only the attributenames will be sent back, not the values
7. Filter
   - expression that describes the entries to be returned
8. attributes
   - a list of comma separated attributes Types to be returned
   - e.g.: cn, telephonenumber
   - can be specified by OID as well, e.g. 2.5.4.3, 2.5.4.20
   - * means all user attributes
   - 1.1 (there is no such attribute OID) for no attributes

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Search Filter Operators

- Equality
  - Only for attributes with equality matching rule
  - e.g.: (cn=Mister X) only entries with common name equals “Mister X”
- Substring
  - Only for attributes with substring matching rule
  - e.g. (cn=Mister*) all entries with cn beginning with “Mister”
- Approximate
  - Implementation dependent
  - e.g.: (cn~=Mister) all entries with cn sounding similiar to “Mister”
- Negation operator
  - e.g. (!(cn=Mister X)) all entries but the one with cn equals “Mister X”

Search Filter Operators (contd.)

- Greater than or equal to and less than or equal to
  - Only for attributes with ordering matching rule
  - e.g. (sn<=Smith) all entries where sn equals “Smith” or is lexicographically above “Smith” (from sn=Adam to sn=smirnow)
  - (age>21) is not possible, use (!(age<=21)) instead
- Presence
  - e.g. (telephoneNumber=*) all entries that contain a telephone number
  - e.g. (objectclass=*) all entries, since every entry contains at least one objectclass

Search Filter Extensions

- LDAPv3 defines an extensible matching filter
  - syntax: attr [“:dn”] [“:” matchingrule] “:=“ value
    - attr is an attribute name
    - “:dn” says that also the attribute in the dn should be searched as well
    - matching rule given by an OID or associated descriptive name
  - examples:
    - (cn:1.2.3.4.5.6:=Mister X) use matching rule 1.2.3.4.5.6 for comparison
    - (o:dn:=company) search for o=company in attributes and also in DN

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Search filter combinations

- Filters can be combined
  - AND operator: **&**
    - e.g. (& (cn=Mister X) (mail=*dot.com)) only entries that have both cn=Mister X and a mail address ending with dot.com
  - OR operator: **|**
    - e.g.: (| (cn=Mister X) (sn=Xerxes)) all entries that have cn=Mister X or sn=Xerxes

Search filter special characters

- Five characters have special meaning
  - must be replaced by an hexadecimal escape sequence if you want to search for them:
  - ´*´ (dec. 42, hex 0x2A) must be replaced with : ´\2a´
  - ´(´ (dec. 40, hex 0x28) must be replaced with : ´\28´
  - ´)´ (dec. 41, hex 0x29) must be replaced with : ´\29´
  - ´\´ (dec. 92, hex 0x5C) must be replaced with : ´\5c´
  - NUL (dec. 0, hex 0x00) must be replaced with : ´\00´
- Example
  - value “A*Star” must be written,
    e.g. (cn=A\2AStar)

LDAP URL (RFC 2255)

- Format:
  - ldap://<host>:<portnumber>/<basedn>?<attrlist>?<scope>?<filter>?<extensions>
- Example:
  - ldap://myhost.org:9999/o=University,c=NL?cn,telephonenumber?subtree?(cn=Mister X)

LDAPv3 Extension mechanisms

- LDAP controls
  - RFC 2251, Par. 4.1.12
  - All 9 LDAP operation (bind, search, add, ...) can be extended
  - controls modify behavior of operation
  - consist of controlType, criticality, [controlValue]
  - client and server must support the control

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LDAPv3 Extension mechanisms contd.

- LDAP extended operations
  - RFC 2251, Par. 4.12
  - new defined protocol operation in addition to the nine
  - ExtendedRequest: requestName, [requestValue]
  - ExtendedResponse: LDAPresult,[responseName, response]
- SASL mechanisms
  - Framing for support of different authentication mechanisms

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Root DSE Entry

- a special entry in the LDAP server
- contains attributes that describe the server:
  - namingContext (which part of the DIT)
  - subschemaSubentry (supported schema)
  - altServer (alternate Server that should contain the same data)
  - supportedLDAPVersion
- has attributes that describe which extensions are supported:
  - supportedExtensions
  - supportedControls
  - supportedSASLMechanisms
- Retrieve the data e.g. by
  - ldapsearch –x –b “” –s base +

LDAPv3 Extension Standardization

- Extensions have to be standardized:
- IETF WG ldapext
  - "successor" of the original LDAP WG asid
  - Charter: www.ietf.org/html.charters/ldapext-charter.html
  - Big Players like Netscape/Sun (= iPlanet), Microsoft and Novell very active in this WG
  - Still some overdue work to be done
  - Also other works than extension definitions
  - Besides this WG a lot of individual submissions
  - Officially closed WG

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RFC 2589

- LDAPv3: Extensions for Dynamic Directory Services, Y. Yaacovi, M. Wahl, T. Genovese. May 1999 (STD)
  - Dynamic entries in the directory
  - periodical refreshing of the information
  - needed, e.g. for person online status information while a video conference
  - Client and server requirements

RFC 2589 contd.

- Defines:
  - ExtendedRequest:
    - RequestName (OID), entryName (DN), requestTtl (Time to live in seconds)
  - ExtendedResponse:
    - LDAPresult enhanced by responseName and responseTtl (Time to live in seconds, may be larger than requested)
  - Objectclass dynamicObject with Attr. EntryTtl
  - RootDSE Attribute:
    - dynamicSubentries

RFC 2649

- An LDAP Control and Schema for Holding Operation Signatures, B. Greenblatt, P. Richard. August 1999 (EXP)
  - Client send modification of an entry on a secure connection (e.g. TLS) and signs this modification with S/MIME certificate, or lets it be signed by the server
  - a complete journal of modifications is stored

RFC 2649 contd.

- Defines:
  - Control SignedOperation
  - Control Demandsignedresult
  - Control SignedResult
  - Objectclass signedAuditTrail with Attribute Changes
  - Objectclass zombiObject with Attribute Changes and originalObject
  - RootDSE Attribute signedDirectoryOperationSupport

RFC 2696

- LDAP Control Extension for Simple Paged Results Manipulation, C. Weider, A. Herron, A. Anantha, T. Howes. September 1999 (INF)
  - Mechanism by which the server can give back several parts of the result
  - Client defines how many entries at a time
  - RFC Defines:
    - Control pagedResultControl
    - searchControlValue: realSearchControlValue
      - size (number of entries)
      - cookie (to re-identify the search request)

RFC 2596

- Use of Language Codes in LDAP, M. Wahl, T. Howes. May 1999 (STD)
  - uses Attribute tag mechanism:AttributeDescription
  - language codes as in RFC 1766
  - Format: <Attr.>;lang-<language code>
  - Example: givenName; lang-en-US
  - is not allowed in DN
  - allowed in:
    - search filter, e.g. (cn;lang-en=X*)
    - compare request
    - requested attribute, e.g. ldap://hist:999/c=NL/cn;lang-en?(objectclass=*)
    - add operation
    - modify operation

RFC 2891

- LDAP Control Extension for Server Side Sorting of Search Results, T. Howes, M. Wahl, A. Anantha, August 2000
  - Client can ask the server to sort the results by specifying an attribute to sort.

LDAP Security Model

- Client authentication at start of the LDAP connection
  - simple bind
    - send a DN and a password that is stored in the userPassword attribute of that entry
    - password gets sent in the clear
  - Simple bind with SSL (Secure Socket Layer): LDAPS
    - whole session is encrypted
  - Simple bind with TLS (Transport Layer Security)
    - StartTLS operation
    - whole session is encrypted

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LDAP Security Model

- Alternatively bind with SASL mechanisms
  - Simple Authentication and Security Layer
  - E.g.:
    - Digest MD5 (challenge response)
    - GSSAPI (Kerberos 5)
    - External: using authentication information established on lower levels (SSL, IPSec)

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LDAP work on X.509: TLS

- RFC 2830: LDAPv3 Extension for Transport Layer Security, May 2000
  - TLS as defined in RFC 2246
  - Client sends Start TLS extended request
  - Server sends Start TLS extended response
  - TLS version negotiation (handshake)
  - Client may bind with SASL mechanism EXTERNAL
  - Client MUST check server identity
  - Client MUST refresh cached server capability information (eg. RootDSE)

LDAP Authentication

- RFC 2829: Authentication Methods for LDAP, May 2000

1. Read only, public directory
   - Anonymous authentication
   - No bind or empty Bind DN
2. Password based authentication directory
   - MUST support DIGEST-MD5 SASL mechanism (RFC 2831)
   - Client binds sasl mechanism DIGEST-MD5
   - Server sends back digest-challenge
   - Client binds again sending digest-response

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LDAP Authentication contd.

3. Directories needing session protection
   - SHOULD use certificate-based authentication with TLS (RFC2830) together with simple bind or SASL EXTERNAL
   - Client uses Start TLS operation
   - Client and server negotiate ciphersuite with encryption algorithm
   - Server requests client certificate
   - Client sends certificate and performs a private key based encryption to prove its posession
   - Server checks validity of certificate and its CA
   - Client binds simple or with SASL "EXTERNAL" mechanism

IETF WG LDAPbis

- Revision of all LDAP core RFCs
- With references to mandatory security mechanism of RFC 2829 and 2830 possible to go for Draft Standard
- No changes in the data definitions
- Some clarifications in wording
- Some SHOULDS to MUST etc.

Current LDAPbis Drafts

- draft-ietf-ldapbis-protocol-07 obsoletes RFC 2251 and portions of RFC 2252
- draft-ietf-ldapbis-models-00 obsoletes portions of RFC 2251, 2252 and 2256
- draft-ietf-ldapbis-syntaxes-02 obsoletes RFC 2252 and portions of 2256
- draft-ietf-ldapbis-dn-07 obsoletes RFC 2253
- draft-ietf-ldapbis-filter-02 obsoletes RFC 2254
- draft-ietf-ldapbis-url-0? obsoletes RFC 2255
- draft-ietf-ldapbis-user-schema-02 obsoletes RFC 2256
- draft-ietf-ldapbis-authmeth-03 obsoletes RFC 2829 and 2830

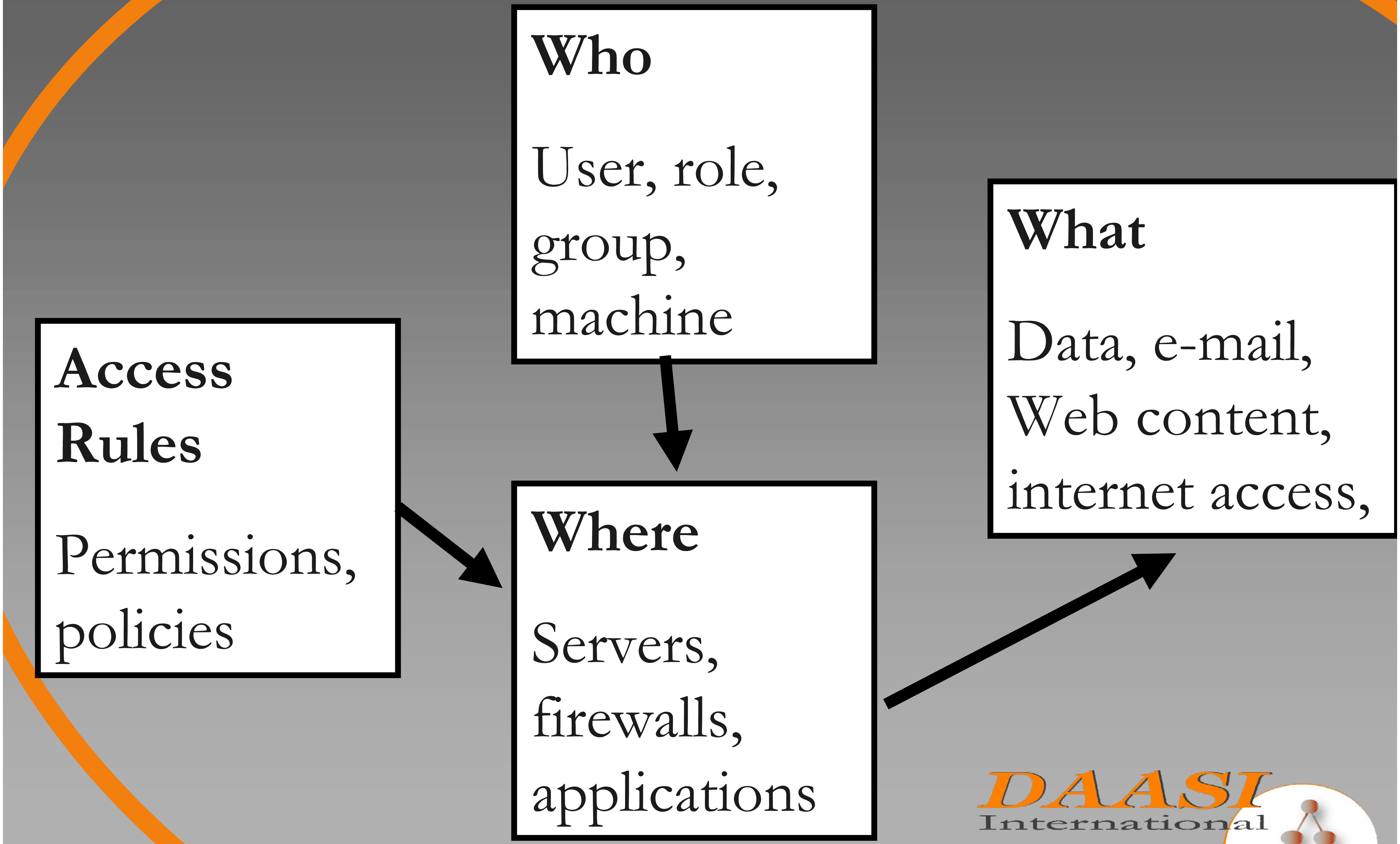
Current LDAPbis Drafts New Documents

1. LDAP: Technical Specification Road Map, Kurt Zeilenga, 21. February 2002
   - draft-ietf-ldapbis-roadmap-00
   - explicitly specify the set of Documents comprising LDAPv3 (RFC 2251-2256 and 2829-2830)
2. IANA Considerations for LDAP, Kurt D. Zeilenga, 12 May 2002
   - draft-ietf-ldapbis-iana-06
   - procedures for registering extensible elements of LDAP

Current LDAPext drafts with unknown status

- Access Control and authentication
  - Access Control model, X.509 Authentication with SASL
- Client Server communication
  - virtual lists, persistent search, referrals, matched values
- APIs
  - C-API and extensions, Java-API and extensions, additional error codes

Access Control



Who

User, role, group, machine

Access Rules

Permissions, policies

Where

Servers, firewalls, applications

What

Data, e-mail, Web content, internet access,

From RL Morgan, PKI Standards Overview

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Access Control Requirements

- **RFC 2820: Access Control Requirements for LDAP, E. Stokes, D. Byrne, B. Blakey, P. Behera. May 2000**
  - Requirements for access control lists
  - easy, efficient, extensible
  - specific policies rule over non specific
  - default policy for new entries
  - sorting of the ACLs irrelevant
  - all ACLs must be explicit
  - ...

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Access Control Model

- Access Control Model for LDAP, E. Stokes, D. Byrne, B. Blakey, <draft-ietf-.ldapext-acl-model-08.txt>, 29 June 2001 (expired!)
  - Access control information attributes for entries and subtrees (entryACI and subtreeACI)
  - Access control information subentry class ldapACISubEntry with attribute accessControlSchemes
  - RootDSE Attribute supportedAccessControlSchemes
  - LDAP functional model (add, delete, modify and search) for the manipulation of access control information
  - Additional control: getEffectiveRightsRequest and –Response for these manipulations

Basic ACI Attributes

- entryACI and subtreeACI with common syntax (Beware: this syntax has changed each new Draft version)
- Format:
  - <Rights> “#” <Attributes> “#” <Subject>

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Basic ACI Attributes contd.

- Rights:
  - "grant:" <permissions> and/or "deny:" <permissions>
  - Permissions for entries:
    - add, delete, export, import, renameDN, browseDN, view, returnDN, unveil (disclose on error), getEffectiveRights
  - Permissions for Attributes:
    - read, write, obliterate, search, search presence only, compare, make
  - permissions for attributes and permissions for entries are never found in a single ACI

Basic ACI Attributes contd.

- Attributes:
  - <attributes> or “[all]” or “[entry]”
  - attributes:
    - <attrDescr >[“,” <attrDescr> …]
    - attrDescr:
      - attributeType [“;” <options>]
      - Options: <option> or option “;” options
- Examples:
  - Cn
  - userCertificate;binary

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Basic ACI Attributes contd.

- Subject:
  - "authnLevel:" <authenticationlevel> “:” <identification>
  - Authenticationlevel:
    - "none" or "weak" or "limited" or "strong“
  - Identification:
    - “public:” or
    - “this:” or "authzId-" <authzId> or
      “role:” <DN> or “group: “ <DN> or “subtree:” <DN> or
    - "ipAddress:" <ipAddressRange(s)> or
      "dns:" <partialdomainname(s)>
    - authzId: "dn:" <DN> or "u:" <userid>

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ACI Examples:

- Grant read, search and compare of all attributes to all:

```
subtreeACI:grant:rsc#
[all]#
authnLevel:none:public:
```

- But deny for sensitive attributes:

```
subtreeACI:deny:rsc#
userPassword,subtreeACI,entryACI,
     salary#
authnLevel:none:public:
```

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ACI Examples contd.

- Let authenticated person modify her entry:

```
entryACI:grant:wo#
[all]#
authnLevel:strong:
authz-ID-dn:cn=ellen,dc=x,dc=com
```

- But let her not change ACIs and salary:

```
entryACI:deny:wo#
entryACI,subtreeACI,salary#
authnLevel:strong:authz-ID-dn:
cn=ellen,dc=x,dc=com
```

LDAP Data Interchange Format LDIF

- **RFC 2849:**
  - The LDAP Data Interchange Format (LDIF) - Technical Specification, G. Good, June 2000
- **Format for exchanging data**
- **Example:**

```
dn: cn=Mister X, o=University, c=NL
objectclass=top
objectclass=person
objectclass=organizationalPerson
cn=Mister X
cn=Xavier Xerxes
mail=X@dot.com
mail=Mister.X@dot.com
telephoneNumber=1234567

dn: cn=next entry, ...
```

Replication

- IETF WG LDUP
  - LDAP Duplication / Replication / Update Protocols
  - Charter: `www.ietf.org/html.charters/ldup-charter.html`
  - Active since 1998 but no RFC yet
  - Multi-master replication makes it very complicated
  - Atomicity issues
  - No single master replication profile yet

Replication

- Vital missing part in LDAP standardization
- Needed to really replace X.500
- Current LDAP implementations have
  - Either proprietary replication mechanisms
  - Or stick to the pseudo standard of University of Michigan implementation (SlurpD)
  - Or just use plain LDIF
  - New possibility: XML (DSML)

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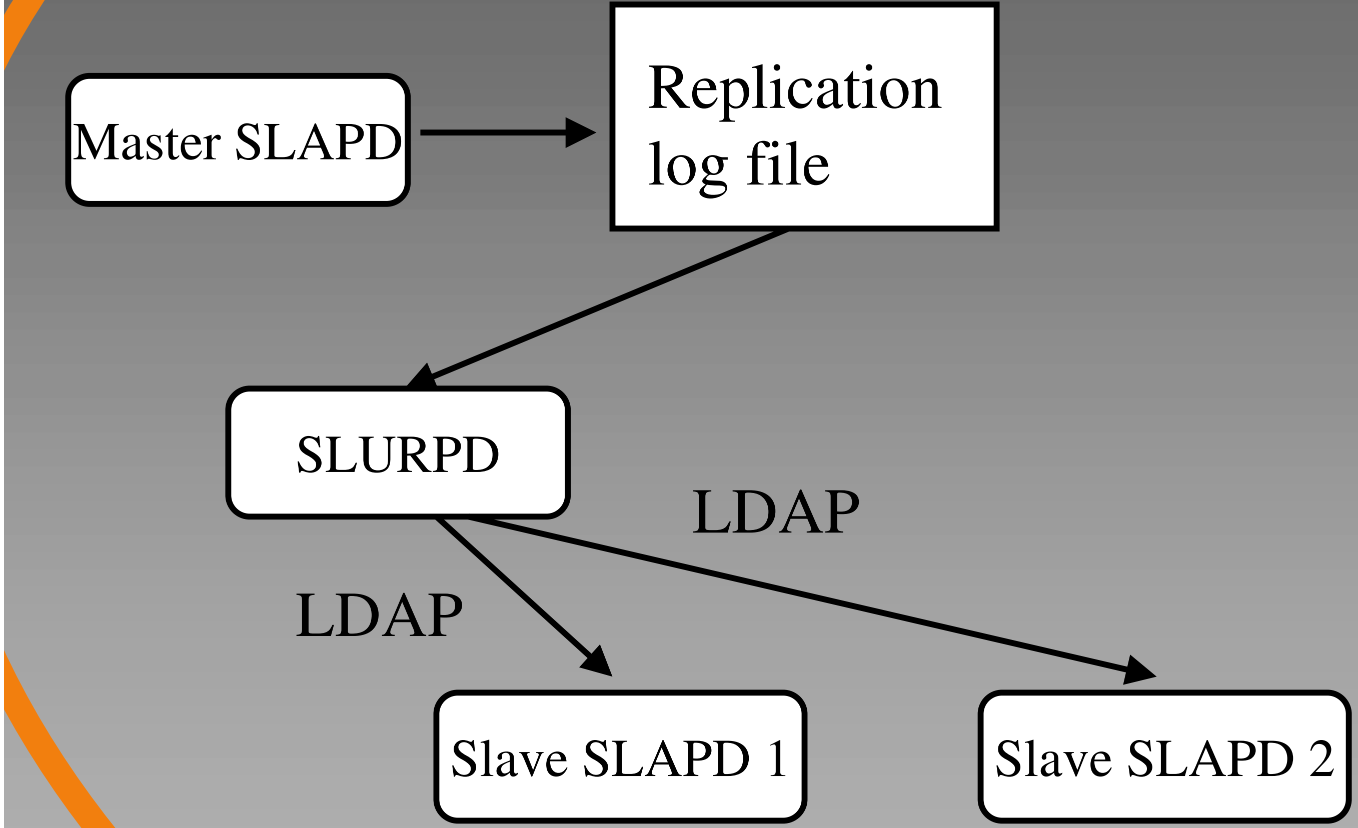
Non Standard LDAP Replication



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Replication log file format

```
replica: host1.hu:9999
replica: host2.hu:8888
time: 960373276
dn: cn=Mister X, o=University, c=HU
changetype: delete

replica: host1.hu:9999
replica: host2.hu:8888
time: 960373277
dn: cn=Mister X, o=University, c=HU
changetype: add
objectclass: top
objectclass: person
objectclass: organizationalPerson
cn: Xavier Xerxes
mail=X@dot.com
mail=Mister.X@dot.com
telephoneNumber=1234567
```

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How to find LDAP Servers

- R. Moats, R. Hedberg: A Taxonomy of Methods for LDAP Clients Finding Servers, <draft-ietf-ldapext-ldap-taxanomy-05>, July 2001

  - Client configuration
  - Well known DNS aliases
  - Referrals
  - SRV records
  - Service Location Protocol

Client configuration

- Simple
- Manual maintanance
- Not scalable

Well known DNS aliases

- RFC 2219: Use of DNS Aliases for Network Services, M. Hamilton, R. Wright, October 1997 (BCP)
  - Either: `ldap.university.nl IN A 194.167.157.2`
  - Or: `ldap.university.nl IN CNAME wp.university.nl`
  - Easy to implement
  - Not widely-used
  - Additional info (baseDN) needed to contact LDAP-server

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Referrals

- Defined in LDAPv3
  - Referral part of LDAPresult to indicate that the server does not have the requested data but the servers referred to might have
  - Format: referral: <LDAP-URL(s)>
- Can be stored in a server
- The exact data model is not standardized yet
  - Subordinate reference and superior reference
- A lot of attempts to standardize usage have failed

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DNS SRV Records

- RFC 2052, RFC 2782 and draft-ietf-dnsext-rfc2782bis-00.txt
  - _Service._Proto.Domain IN SRV Priority Weight Port Target
  - Used in draft-zeilenga-ldap-root-01.txt: „OpenLDAP Root Service - An experimental LDAP referral service“
- DNS SRV *and* referrals:
  - draft-zeilenga-ldapnsref-00.txt
    - Objectclass dNSReferral
    - Ref: ldap:/// + SRV -> complete referral

DNS SRV Records contd.

- **DNS SRV and URIs:**
  - draft-andrews-http-srv-00.txt
    - Can be used for looking up ldap ports
    - Conflict resolution: ports in URI and SRV RR
- **DNS SRV and PKIX:**
  - draft-ietf-pkix-pkixrep-00.txt
  - PKIX Repository Locator Service for:
    - LDAP
    - HTTP
    - OCSP

Service Location Protocol

- V2: RFC 2608
  - Service template for LDAP
  - Highly sophisticated protocol
    - Uses multicast
    - User Agent – Service Agent
    - User Agent – Directory Agent – Service Agent
  - Rather designed for intranets

What can we do with Directories

LDAP for NIS

- RFC 2307: An Approach for Using LDAP as a Network Information Service, L. Howard, March 1998
  - Defines mechanisms for mapping entities related to TCP/IP and the UNIX system to LDAP
  - Deployment of LDAP as an organizational nameservice
  - Software available at: http://www.padl.com/nss_ldap.html

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LDAP for NIS

- Defines objectclasses for:
  - UNIX user (/etc/passwd and shadow file)
  - Groups (/etc/groups)
  - IP services (/etc/services)
  - IP protocols (/etc/protocols)
  - RPCs (/etc/rpc)
  - IP hosts and networks
  - NIS network groups and maps
  - MAC addresses
  - Boot information

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LDAP for unified authentication

- Each user only needs a single username or ID and password for all systems
- Usable for e.g. : IMAP, POP, SMTP auth, FTP, HTTP auth, RSH, SSH, etc. etc.
- Based on PAM (Pluggable Authentication Modules)
  - Authentication management;
  - account management
  - Session management
  - password management

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LDAP for unified auth.

- PAM_LDAP
  - Module for account /password/authentication management with LDAP
  - Software available at: http://www.padl.com/pam_ldap.html
- Plaintext SASL mechanisms can make use of PAM_LDAP

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Questions?

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