DS 2010 naming

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Naming in Distributed Systems

Unique identifiers **UIDs** e.g. 128 bits

- are never reused
- refer to the same thing at all times, or to nothing at all

UIDs should be location-independent! Can the named object be moved?

Pure and impure names (as Needham called them)

pure names

- the name itself yields no information, and commits the system to nothing
- it can only be used to compare with other similar names e.g. in table look-up

impure names

- the name yields information,
- commits the system to maintaining the context in which it can be resolved

Examples of impure names

foo@cl.cam.ac.uk name of a person, registered in a DNS domain
foo@lcs.mit.edu name of a person, registered in another DNS domain
another or the same person?

puccini.cl.cam.ac.uk name of a machine, registered in a DNS domain

(disc-pack-ID, object-ID) Bad idea from history of naming files and directories.
Seemed efficient until the objects had to be moved

(host-ID, object-ID) OK, it's impure .... but how are pure names generated in a DS?
We must not have centralised name allocation.
(***host-ID, object-ID)*** has been used (badly) in middleware,
and has made the objects unmoveable.
It could be used to generate pure names,
if we do not make use of the separate fields. Typical example:

32-bit host-ID	96 bit object-ID

Unique names

Both pure and impure names can be unique.
Uniqueness has to have a context

for impure names:

- hierarchical names: scope of uniqueness is level in hierarchy
  (uniqueness is within the names in the directory in which the name is recorded)

for pure names

- a bit pattern: flat, system-wide uniqueness (what else is there?)

Problems with pure names:

- where to look them up to find out information about them?
- how do you know that an object does not exist? How can a global search be avoided?
- how to engineer uniqueness reliably in a distributed system?
  centralised creation of names? As discussed above, ***(host-ID, object-ID)***?

Problems with impure names:

- how to restructure the namespace
  e.g. when objects move about such as when companies restructure

Examples of (pure/impure) names - unique identification

UK national insurance - allocated on employment
US Social Security - allocated on employment
Passport
Driving licence
Services: RAC, AA, AAA(US), AAA(Aus)
Credit cards
Bank accounts
Utilities' customer numbers: gas/electricity/water/phone
Charity members
Loyalty card members

For the above examples:

- Is the structure explicit or implicit?
- Is allocation centralised or distributed?
- What is the resolution context?

More examples of names - unique identification?

UK health service (NHS) ID

but hospitals still use local patient numbers with names recorded at the time
e.g. is J. Ken Moody the same person as John K. Moody?
can medication information be used interchangeably?

Professional societies: BCS, ACM, IEEE

Tale of woe from Jean Bacon: Jean Bacon is not unique and is therefore unsuitable as a database key. Jean Bacon in Connecticut USA and I were allocated the same IEEE membership number with merged records: Cambridge work, Connecticut home. IEEE membership would not believe me until I found her and we emailed them together.

e.g. from the Computer Lab, Jatinder Singh is held up at immigration
because he shares the name and date of birth of another Jatinder Singh

Telephone company analogy – wired service

Geographically partitioned distributed naming database.

Electronic version is current, paper directories are an official cache
Frequency of update (some years ago):
Cambridge area 1,000,000 entries, 5,000 updates a week

Given a name e.g. (Yudel Luke), or (Yudel Luke, 3 Acacia Drive) which directory to use?

- don't know where to look up pure names

Lookup doesn't yield useable information:
Call# **->** unobtainable, where # is from the official cache (paper directories)
we detect out-of-date values, call directory enquiries, cache unofficially
Call# **->** unobtainable, for a number that we know and use often, or from personal address book
redial, report fault, check official cache, ask social network if X has moved phone

Can't find an entry in the official cache (exact matching required)
e.g. Phillips - check spelling – Philips
e.g. try acronyms S.S. for Social Services

BT offer a web service *www.thephonebook.com* (name and address -> number)
only offers exact matching e.g. Philips not suggested for Phillips (do you mean?)
search engine approaches are used to augment directory lookup

Name spaces and naming domains

In general, provide clients with values of attributes of named objects

Name space

- the collection of valid names recognised by a name service
- a precise specification is required, giving the structure of names

e.g. ISBN:1-234567-89-1 namespace identifier, namespace-specific string
/a/b/c/d file system pathname, variable length, hierarchical
puccini.cl.cam.ac.uk DNS machine name – see case study below
128 bit system-wide OS port name for Mach

Naming domain

a name space for which there exists a single overall administrative authority
for assigning names within it
this authority may delegate name assignment for nested sub-domains (see DNS below)

Name resolution - binding

Name resolution or binding
obtaining a value for an attribute of the named object that allows the object to be used

Late binding is considered good practice
Programs should contain names, not addresses

file-service? → name service
IP-address, port# (, timestamp maybe) ← name service

A machine may fail and the service move to another machine.
Your local agent may cache resolved names for subsequent use,
and may expire values based on timestamps (TTL time-to-live)

Cached values are always used "at your own risk".
They should not be embedded in programs.

If cached values don't work, the lookup has to be repeated.
Lookup may be iterative for large-scale systems – see later.

Names, attributes and values stored in a name service

example:

object type	attribute list
user	login-name, mailbox-hosts(s)
computer	architecture, OS, network-address, owner
service	network-address, version#, protocol
group	list of names of members
alias	canonical name
directory?	list of hosts holding the directory (may be held in a separate structure rather than as a type of name, as here)

Directories are likely to be replicated for scalability, fault-tolerance, efficiency, availability

Directory names often resolve to a list of hosts plus their addresses to avoid an extra lookup per host

Attribute-based (inverse) lookup may be offered – a YELLOW PAGES style of service for object discovery e.g. X.500, LDAP

Names, attributes and values - examples

object type -> list of attribute names

name service holds:

object-type, object-name -> list of attribute values

You can acquire a standard directory service e.g. LDAP and use it to store whatever your service/application needs

querying:

object-type, object-name, attribute-name -> attribute value

computer, puccini.cl.cam.ac.uk, address **->** IP-address
user, some-user-name, public-key **->** PK bit pattern

checking:

object-type, object-name, attribute-name, attribute value -> yes/no

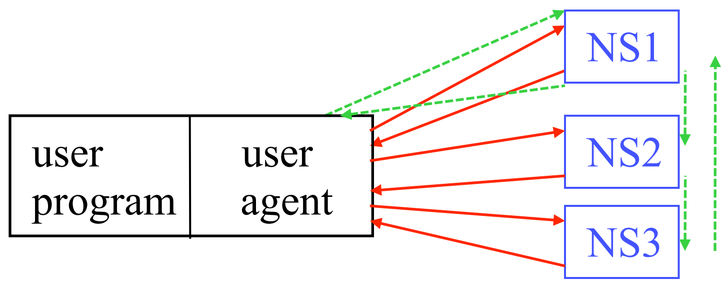
ACL, filename, some-user-name, write-access **->** yes/no

Attribute-based (inverse) lookup:

object-type, attribute-name, attribute value -> list of object-names

computer, OS version#, OS version# value -> list of computers

Iterative name resolution



user agent (UA) starts from the root address of the name service, or tries some well-known sub-tree root, e.g. the location of the ***uk*** directory may be used by agents in the UK

To resolve ***cl.cam.ac.uk*** there are two alternatives

look up ***ac***'s address in uk, then look up ***cl***'s address in ***ac***
The UA will cache resolved names as hints for future use

any name server will take a name, resolve it, and return the resolved value

The client may be able to choose, e.g. select "recursive" in DNS

Engineering optimisations:
  use of caching at UA and at directories
  try cached values first

Name services - used to be hot stuff!

DNS Internet Domain Name System, see below

Grapevine: Xerox PARC early 1980's, *Birrell, Levin, Needham, Schroeder CACM 25(1) 1982*
two-level naming hierarchy e.g. ***name@registry*** ***birrell@pa***
primarily for email, but also gave primitive authentication and access control
(check password as attribute of user, check ACL)
any Grapevine server would take any request from a GV user agent

Clearinghouse, Xeroc PARC, Oppen and Dalal 1983
ISO standard based on an extension of Grapevine
three-level hierarchy

GNS Global Name Service, DEC SRC, *Lampson et al. 1986* - see below
full hierarchical naming
support for namespace restructuring

X.500 and LDAP, see below

Name services in Middleware
CORBA: naming and (interface) trading services, Java JNDI, Web W3C: UDDI
Allow registration of names/interfaces of externally invocable components with interface references and attributes such as location
May offer separate services for: ***name –> object-reference, object-reference –> location***

Case Study: DNS - Internet Domain Name System

Before 1987 the whole naming database was held centrally and copied to selected servers periodically
The Internet had become too *large scale* and a *distributed, hierarchical scheme* was needed
(*Paul V. Mockapetris, 1987*)

What does DNS name?

In practice, the objects are:
- computers
- servers such as mail hosts

...but can be other crazy things

The directory structure (resolution context) is captured as:
- domains

Domains are, in fact, one of the objects that DNS names.

DNS – Definition of names

Definition of names

hierarchy of components (labels), highest level in hierarchy is last component, total max 255 chars

label: max 63 chars, case insensitive, restrictions on the character set (but people are talking Unicode and http://وزارة-الأتصالات.مصر/ works so...)

final label of a fully qualified name can be:

3-letter code: type of hosting organisation
edu, gov, mil are still US-based, others, e.g. ***com, net, org, int***, can be anywhere

2-letter code: country of origin defined by ISO e.g. ***uk, fr, ie, de***, ...
other stuff e.g. ***eu***

final 2-letter label doesn't always imply country of location of host , but where the host was registered
e.g. www.yahoo.co.uk has been in Germany
e.g. ISO have defined many small "country of origin" domains such as ***to, cc, bv***, ...

arpa: for inverse lookup, e.g.
170.9.232.128.in-addr.arpa
1.0.0.0.0.0.e.f.f.f.0.0.0.0.0.0.4.1.0.1.d.1.1.0.8.4.3.0.1.0.a.2.ip6.arpa

Examples of domain names:
mit.edu
cl.cam.ac.uk
cs.tcd.ie
tu-darmstadt.de

DNS

Computers using DNS are grouped into zones e.g. ***uk, cam***
Within a zone, management of nested sub-domains can be delegated
e.g. ***cl*** is managed locally by the domain manager who adds names to a local file (though, conceptually, this can be a database or whatever)
Each zone has a primary name server that holds the master list for the zone. Secondary name servers hold replicas for the zone.

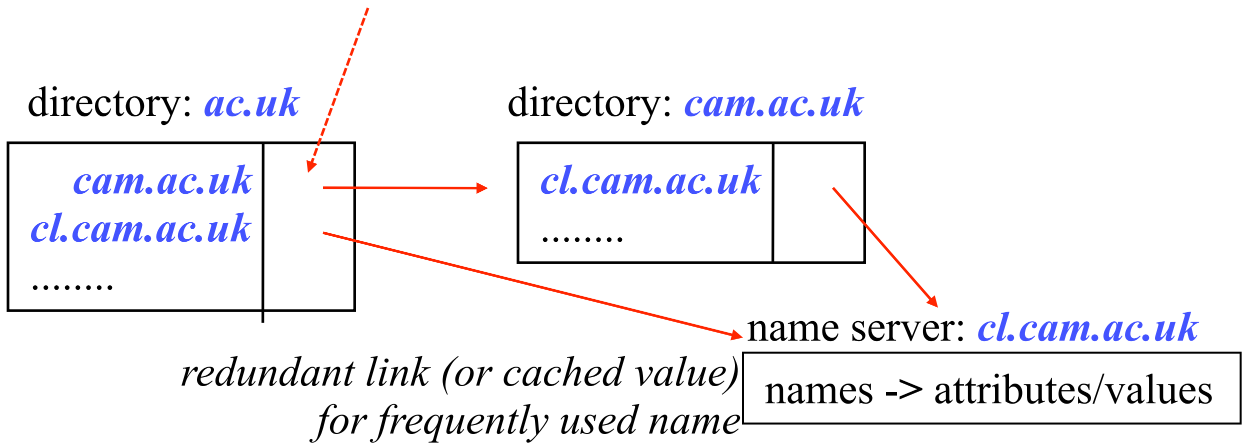
Queries can relate to individual hosts or zones/domains, examples:

query			response
A	computer name	->	IPv4 address
AAAA	computer names	->	IPv6 address
MX	mail host for domain	->	list < host, preference, IP address >
	includes mail hosts for detached computers		
NS	DNS servers for a domain	->	list < host, authority?Y/N, IP address >

...and many more

DNS name servers – note the large scale

The domain database is partitioned into directories that form a distributed namespace
We need a starting point for name resolution
DNS directory addresses can be looked up for a domain
yielding: IP address, well-known port



Directories are replicated for availability and good response (primary and secondaries per domain)
Authorised name server for domain is distinguished - weak consistency of secondaries with primary
Resolved queries are cached with a TTL (time to live)
(by user agents and directories) – works because *naming data tends to be stable*
Queries and responses may be batched into composite query messages

DNS design assumptions and future issues

DNS and other name services were designed, in the days of desktops,
on the assumption that objects are static, so that cached values continue to work, update rates are low, etc.

With huge data centres and high bandwidth available, is it time to re-centralise to a few first-class servers? See Tim Deegan's thesis (examined by Paul Mockapetris) and:
T Deegan, J Crowcroft and A Warfield,
"The MAIN name system, an exercise in centralized computing"
ACM SIGCOMM 35(5), Oct 2005.

New issues relate to mobile devices and myriad small devices including sensors

Mobile devices may attach anywhere worldwide
device's MAC address is a UID, IP address?
see comms. courses for details of protocols

Name service design: Replication and Consistency

Directories are replicated for scalability, availability, reliability , ...

How should propagation of updates between replicas be managed?

lookup (arguments) **< - >** is the most recent value known, system wide, guaranteed to be returned?

If system-wide (strong) consistency were guaranteed this would imply:

- delay on update
- delay on lookup

It is essential to have fast access to naming data
– so we relax the consistency requirement

Is this justified?

Name services – assumptions to justify weak consistency

Design assumptions were as below, but new issues have arisen

- naming data change rarely,
- changes propagate quickly,
- inconsistencies will be rare

  YES – information on users and (some) machines
  NO – distribution lists (see analysis of how Grapevine outgrew its specification)
  NEW – mobile users, computers, and small devices e.g. Internet-enabled phones
  NEW – huge numbers of devices to be named – does the design rely on low update traffic?

- we detect obsolete naming data when it doesn't work
  YES – users
  NO – distribution lists

- If it works it doesn't matter that it's out of date
  - you might have made the request a little earlier
  - recall uncertainties over time in DS

Consistency – vs - Availability

We have argued that availability must be chosen for name services, so use weak consistency
When only weak consistency is supported:

lookup (arguments) **- >** returns either: value, version# / timestamp
or: not known at time of last update

Examples:

Service on failed machine, restart at new IP address – update directory(s) – rare event
User changes company – coarse time grain
Companies merge – coarse time grain
Change of password – takes time to propagate – insecurity during propagation
Changes to ACLs and DLs – insecurity during propagation
Revocation of users' credentials – may have been used for authentication/authorisation at session start – can the effect be made instantaneous?
Hot lists e.g. stolen credit cards – must propagate fast – push rather than pull model

Lessons:

Note design assumptions
Take care what data the name service is being used for
Does the service offer notification of change, on registration of interest, as in active databases?

Long-term Consistency

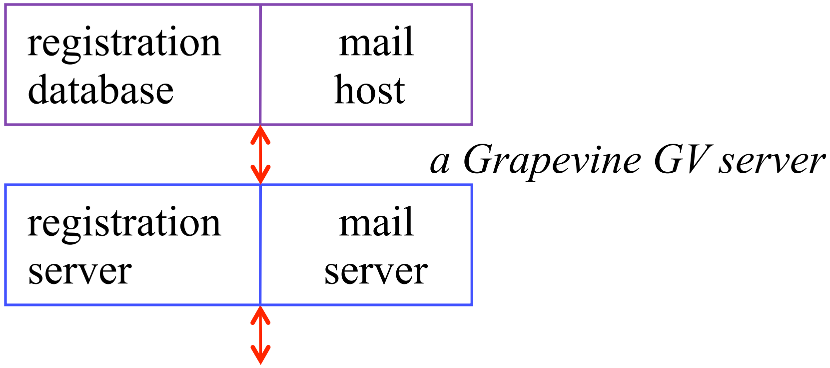
Requirement:
If updates stopped there would be consistency once all updates had propagated
Note that failure and restart behaviour must be specified for updates to propagate reliably

This requirement cannot be tested in a distributed system
- no guarantee that there will be periods of quiescence (no activity)

Updates are propagated by the message transport system
- conflicting updates might arrive out of order, from different sources
- need an arbitration policy based on timestamps
- but recall unreliability of source timestamps, so outcomes of an agreement protocol may not meet the *external* requirements.

Name services typically exchange whole directories periodically and compare them.
The directory is tagged with a new version# after this consistency check
e.g. GNS declares a new "epoch"

Example: Grapevine – the first?



Note that small scale allows a simple design with rapid navigation
2D names ***name@registry***
Every GV server contains the GV registry that contains, for all GV registries worldwide,
registry-name -> list of addresses where registry is held
2 types of name within a registry
group-name -> list of members for distribution lists, also used for ACLs
individual-name -> attributes such as password, mail-host-list, ...

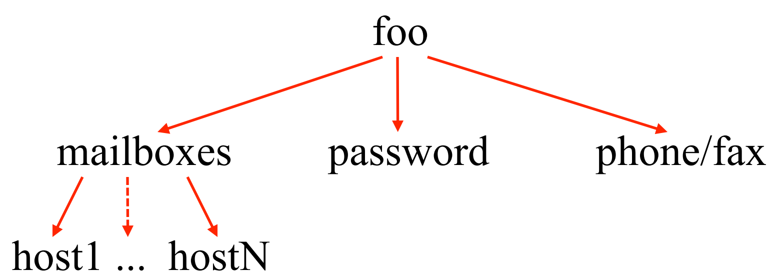
Problems – soon outgrew its specification of #servers, #clients
huge distribution lists were not foreseen
client mail transport protocol used for system updates – could be held up

Global Name service GNS (DEC – 1986)

Lampson, Designing a Global Name service, Proc 5th ACM PODC, 1986

Aims: long life – allowing many changes in the organisation of the namespace
large scale – an arbitrary number of names and domains

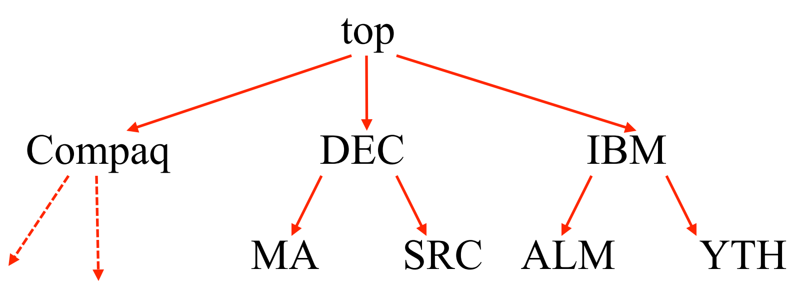
Names
Define 2D names of the form < directory-name, value-name >
where value-names may be a tree such as:

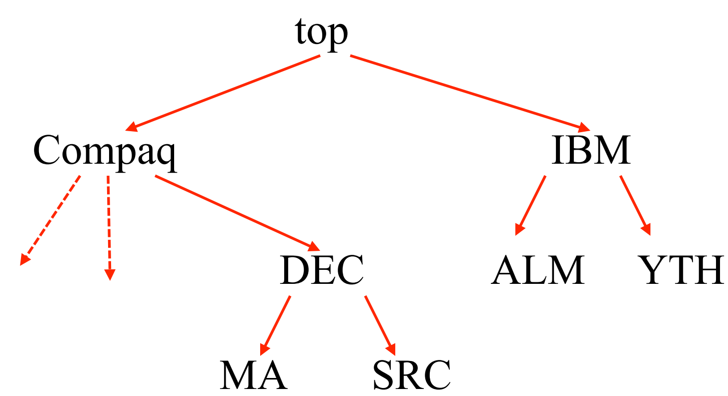


The GNS directory structure is hierarchical
Every directory has a Directory Identifier (DI), a UID *the novel design aspect of GNS*
A full name is any name starting with a DI
- doesn't require a root directory
- doesn't rely on the availability of some root directory

GNS namespace reconfiguration

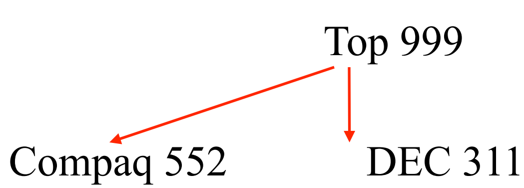
If the directory hierarchy is reconfigured, a directory may still be found via its DI
Names starting with that DI do not change if the reconfiguration is above that DI

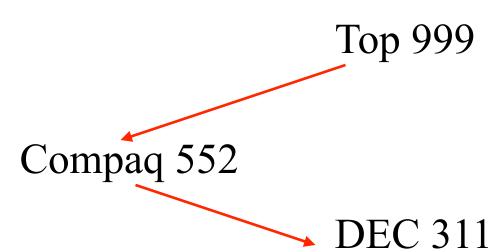




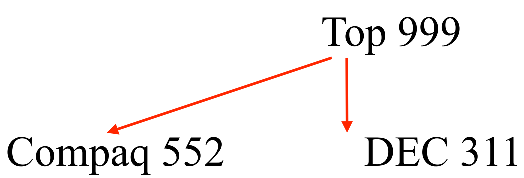
old names still work below the DEC directory

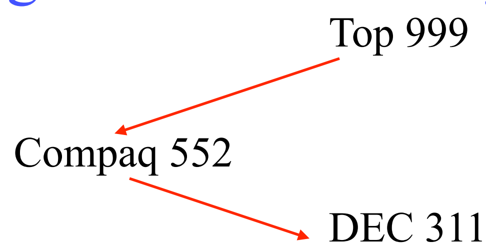
Support is needed by the directory service to locate a directory from its DI
a DI is a pure name – where do we look it up?
Directories usually map directory pathnames to IP addresses
In addition, top level GNS directories store DIs with directory names, e.g.





GNS namespace reconfiguration – directory updates





Names starting from DEC: ***311/SRC, birrell*** do not change. DEC is always 311
Names starting above DEC: ***999/DEC/SRC, birrell -> 999/Compaq/DEC/SRC, birrell***

Directory entries include – DIs with directory names
– pathnames from root

552 = 999/Compaq 311 = 999/DEC n = 999/DEC/SRC	IP addresses

552 = 999/Compaq 311 = 999/Compaq/DEC n = 999/Compaq/DEC/SRC	IP addresses

X.500 Directory Service (White and yellow pages)

ISO and CCITT standard, above OSI protocol stack
More general than most name services where names must be known precisely
and are resolved to locations
Components:
DIT directory information tree
DSA directory service agent
DUA directory user agent
DAP directory access protocol

X.500 is resource-consuming and difficult to use

1993 major revision including replication, access control, schema management,
But X.500 was not accepted as a generic name service
X.509 certificates for authentication and attributes/authorisation have been successful

LDAP Lightweight Directory Access Protocol, *Howes, Kille, Yeong, Robins, 1993*
accepted by IETF – widely used
- access protocol built on TCP/IP
- heavy use of strings, instead of ASN.1 data-types
- simplification of server and client
- current status V3
- LDUP duplication and update protocol being developed

Naming Postlude

Naming for the Internet, see DNS
Naming for companies, worldwide, motivated Grapevine, see also GNS
Standard name services, X.500, LDAP

Naming for the web – document names are based on internet naming

scheme://host-name:port/pathname at host

scheme = protocol: http, ftp, local file

host-name = web server's DNS address, default port 80

pathname is in web server's filing system of file containing data for web page

e.g. http://www.cl.cam.ac.uk/research/

Also, W3C have defined standards for web services (see Middleware)
with message content expressed in XML

SOAP – simple object access protocol

WSDL – web service description language

UDDI – universal description, discovery and integration
(directory service with web service descriptions in WSDL)