Distributed Systems
High-Performance Networks
Clusters and Computational Grids

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Course Objectives

In this the course we are going to presented the *distributed systems*, *high performance networks*, *clusters* and *computational grids* environments.

In the end, participants will have a good idea of the basis of these subjects in both theoretical and practical aspects.

Course Outline

- Distributed Systems
- High Performance Networks
- Clusters and Computational Grids

Course Outline

Distributed Systems

In this part of the course we will cover the following aspects of the distributed systems :

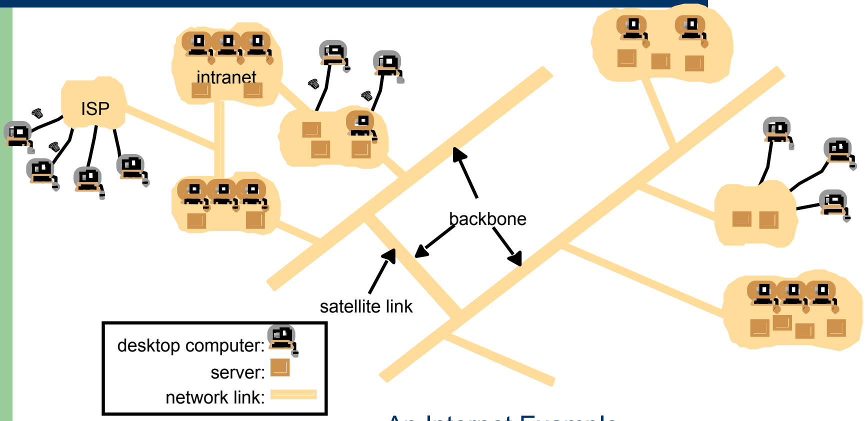
- Characteristics
- Architectural Models
- Networking and Internetworking
- InterProcess Communication (IPC)
- Distributed File System (DFS)
- Name Services (NS)

Course Outline

The recommended literature are presented below and we base our course in the first book.

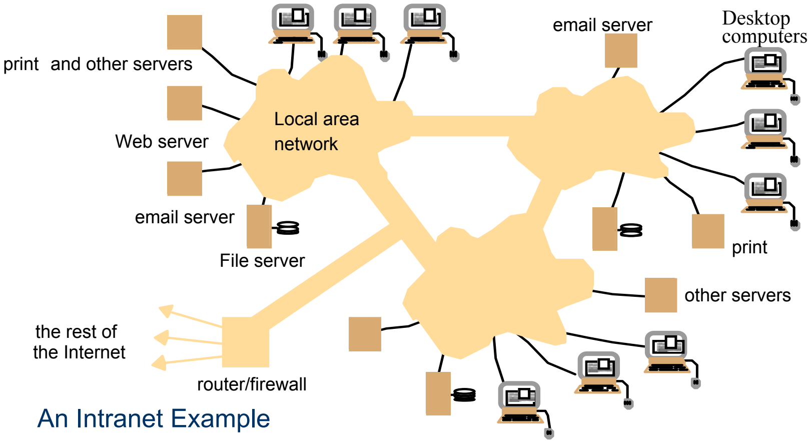
- *Distributed Systems: Concepts and Design, 3rd Edition*, G. Coulouris, J. Dollimore, T. Kindberg, Addison-Wesley, August 2000, ISBN 0201-61918-0.
- *Distributed Systems: Principles and Paradigms*, Andrew S. Tanenbaum, Maarten Van Steen, Prentice Hall, 2002, ISBN 0130888931.

Distributed Systems - Characteristics



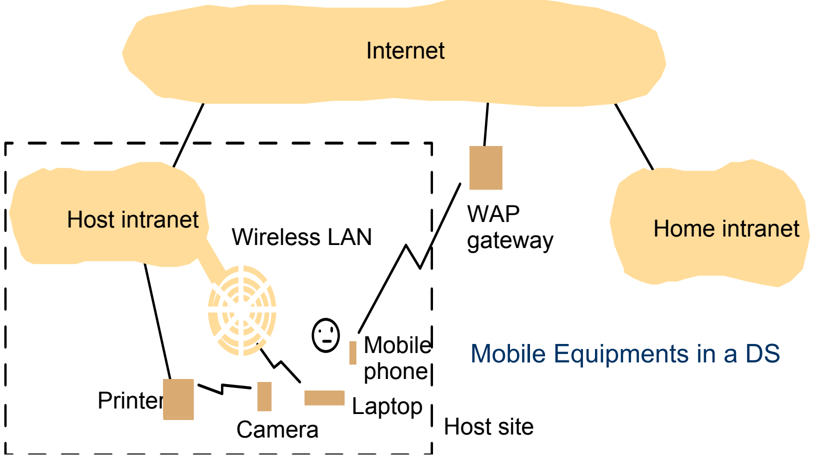
An Internet Example

Distributed Systems



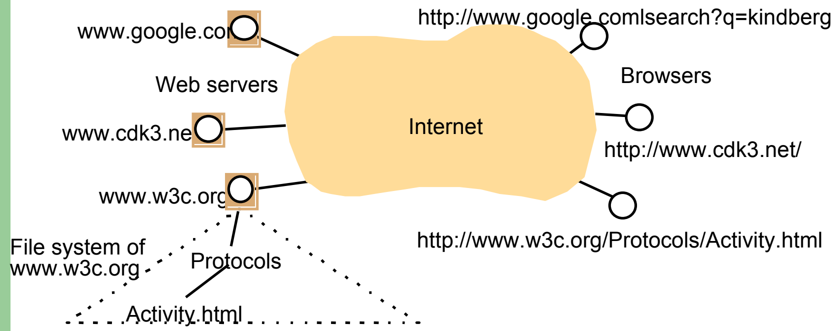
An Intranet Example

Distributed Systems



Mobile Equipments in a DS

Distributed Systems



Web servers and web browsers

Distributed Systems

Date	Computers	Webservers
1979 – December	188	0
1989 – July	130,000	0
1999 – July	56,218,000	5,560,866

Distributed Systems

Date	*Computers*	*Web servers*	*Percentage*
1993, July	1,776,000	130	0.008
1995, July	6,642,000	23,500	0.4
1997, July	19,540,000	1,203,096	6
1999, July	56,218,000	6,598,697	12

Distributed Systems

Transparencies

Access transparency: enables local and remote resources to be accessed using identical operations.

Location transparency: enables resources to be accessed without knowledge of their location.

Concurrency transparency: enables several processes to operate concurrently using shared resources without interference between them.

Replication transparency: enables multiple instances of resources to be used to increase reliability and performance without knowledge of the replicas by users or application programmers.

Distributed Systems

Transparencies

Failure transparency: enables the concealment of faults, allowing users and application programs to complete their tasks despite the failure of hardware or software components.

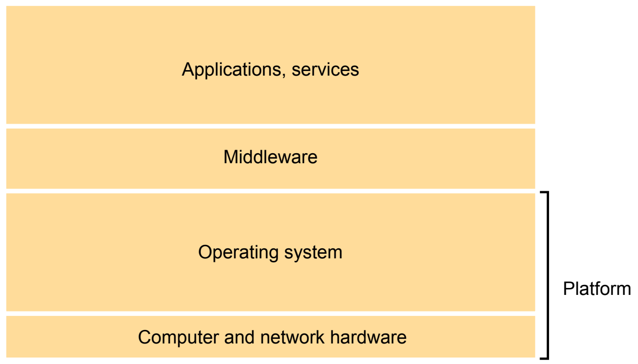
Mobility transparency: allows the movement of resources and clients within a system without affecting the operation of users or programs.

Performance transparency: allows the system to be reconfigured to improve performance as loads vary.

Scaling transparency: allows the system and applications to expand in scale without change to the system structure or the application algorithms.

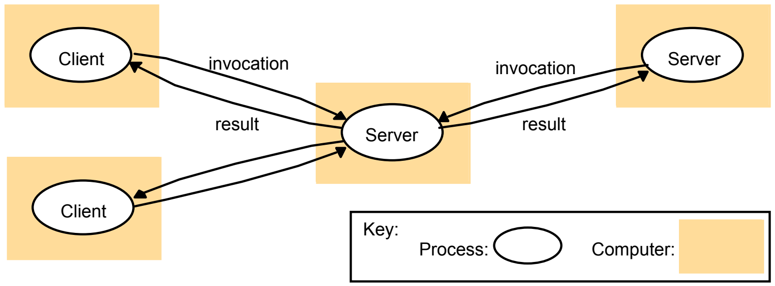
Distributed Systems – Architectural Model

Architectural Models



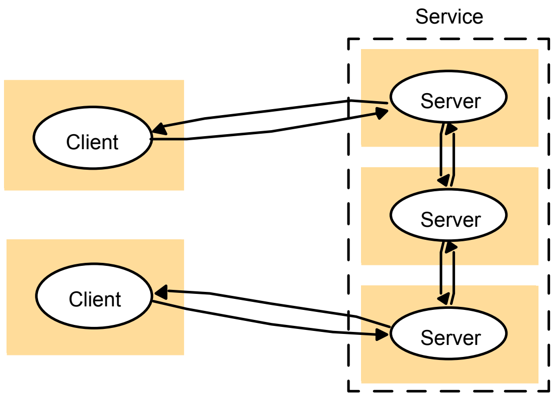
Distributed Systems

Clients invoke individual servers



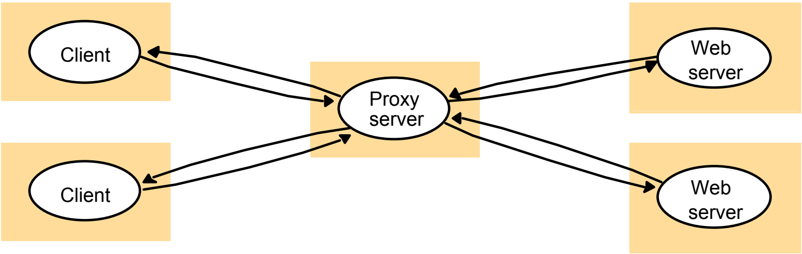
Distributed Systems

A service provided by multiple servers



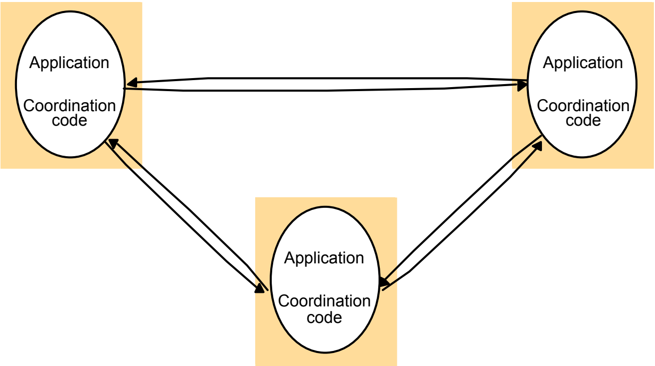
Distributed Systems

Web proxy server



Distributed Systems

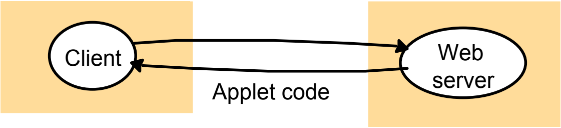
A distributed application based on peer processes



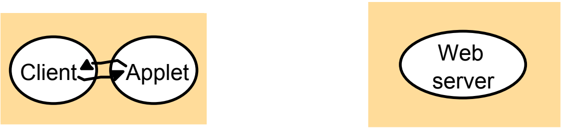
Distributed Systems

Web applets

a) client request results in the downloading of applet code



b) client interacts with the applet

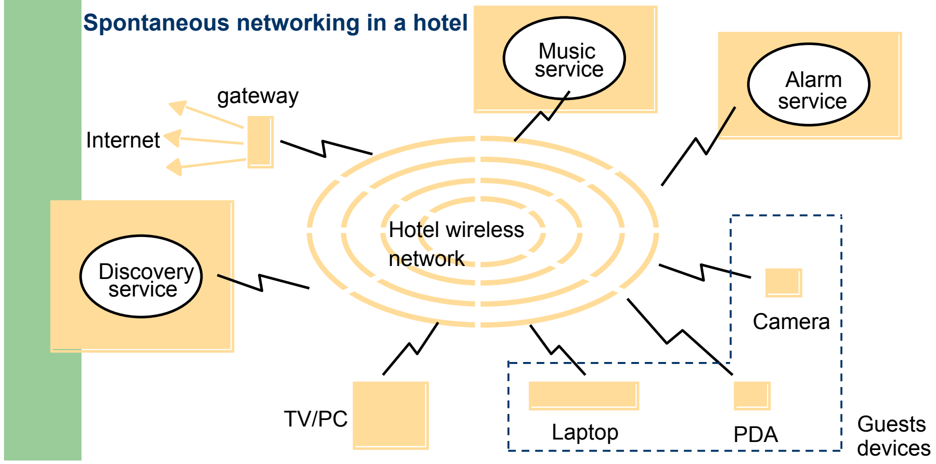


Distributed Systems

Thin clients and compute servers

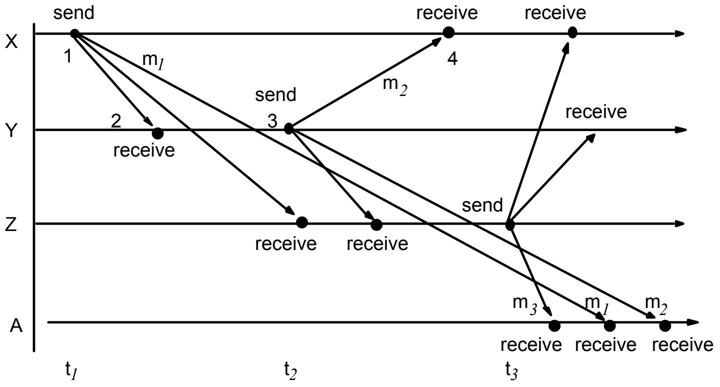
Distributed Systems

Spontaneous networking in a hotel



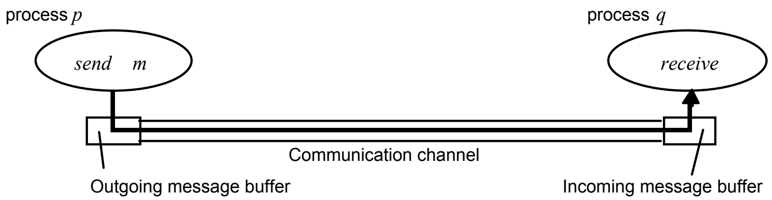
Distributed Systems

Real-time ordering of events



Distributed Systems

Processes and channels



Omission and arbitrary failures

Distributed Systems

Class of failure	*Affects*	*Description*
Fail-stop	Process	Process halts and remains halted. Other processes may detect this state.
Crash	Process	Process halts and remains halted. Other processes may not be able to detect this state.
Omission	Channel	A message inserted in an outgoing message buffer never arrives at the other end's incoming message buffer.
Send-omission	Process	A process completes a *send*, but the message is not put in its outgoing message buffer.
Receive-omission	Process	A message is put in a process's incoming message buffer, but that process does not receive it.
Arbitrary (Byzantine)	Process or channel	Process/channel exhibits arbitrary behaviour: it may send/transmit arbitrary messages at arbitrary times, commit omissions; a process may stop or take an incorrect step.

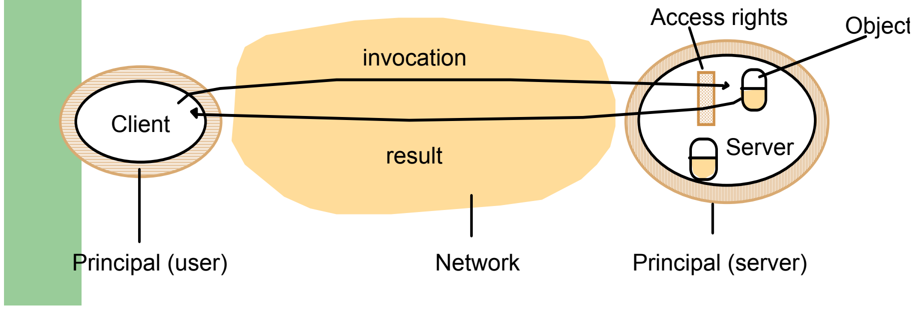
Distributed Systems

Timing failures

Class of Failure	*Affects*	*Description*
Clock	Process	Process's local clock exceeds the bounds on its rate of drift from real time.
Performance	Process	Process exceeds the bounds on the interval between two steps.
Performance	Channel	A message's transmission takes longer than the stated bound.

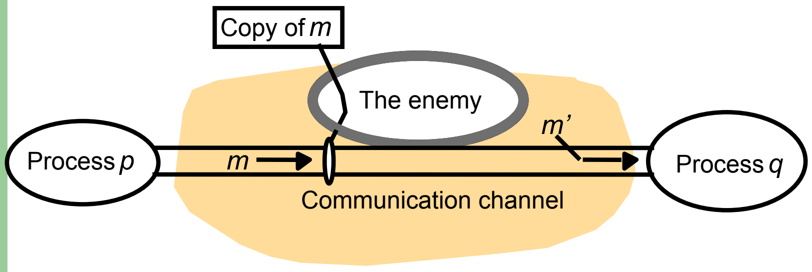
Distributed Systems

Objects and principals

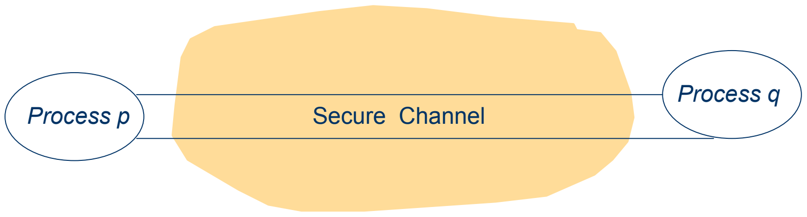


Distributed Systems

The enemy



Distributed Systems

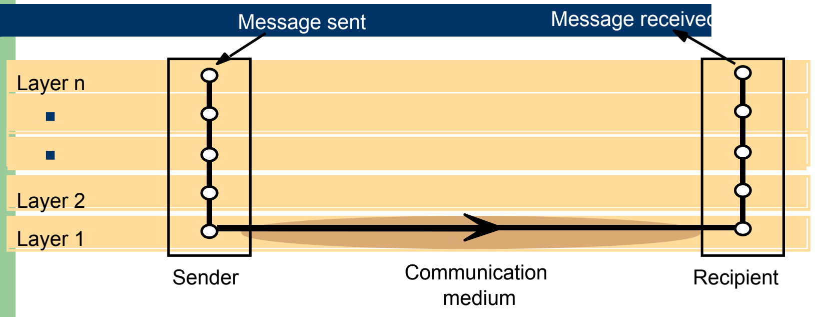


Distributed Systems – Networking and Internetworking

	Range	*Bandwidth (Mbps)*	*Latency (ms)*
LAN	1-2 kms	10-1000	1-10
WAN	worldwide	0.010-600	100-500
MAN	2-50 kms	1-150	10
Wireless LAN	0.15-1.5 km	2-11	5-20
Wireless WAN	worldwide	0.010-2	100-500
Internet	worldwide	0.010-2	100-500

Network types

Distributed Systems



Message sent

Message received

Layer n

▪

▪

Layer 2

Layer 1

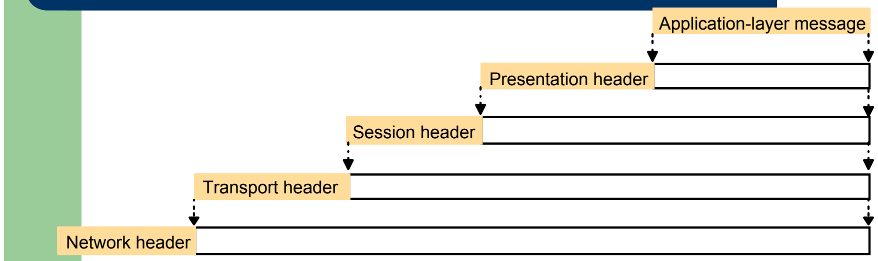
Sender

Communication medium

Recipient

Conceptual layering of protocol software

Distributed Systems



Application-layer message

Presentation header

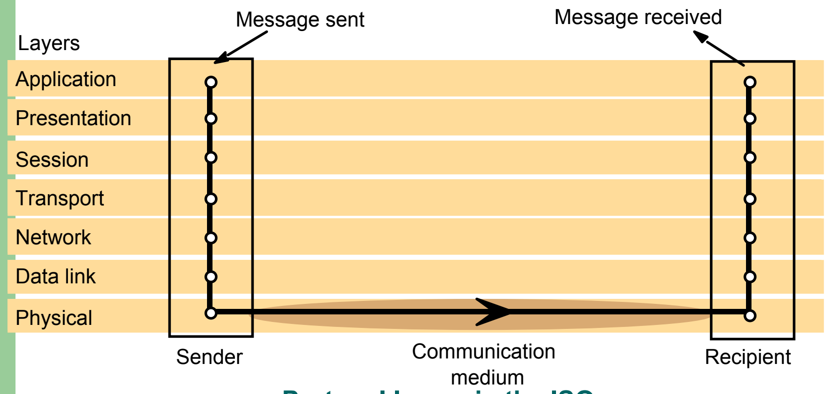
Session header

Transport header

Network header

Encapsulation as it is applied in layered protocols

Distributed Systems



Message sent

Message received

Layers

Application

Presentation

Session

Transport

Network

Data link

Physical

Sender

Communication medium

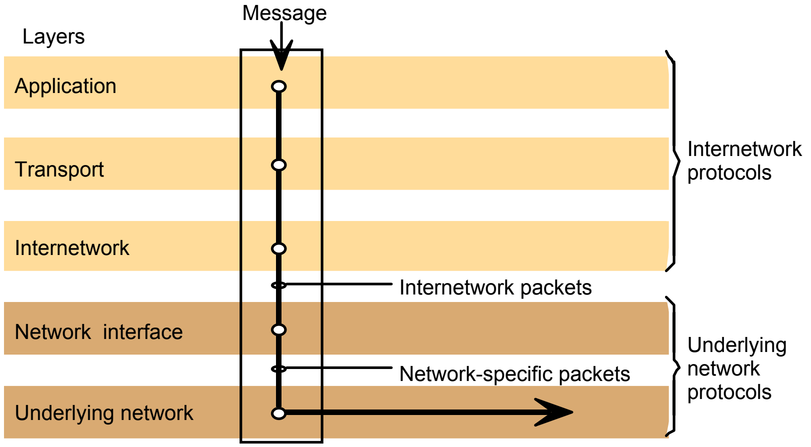
Recipient

Protocol layers in the ISO Open Systems Interconnection (OSI) model

Distributed Systems

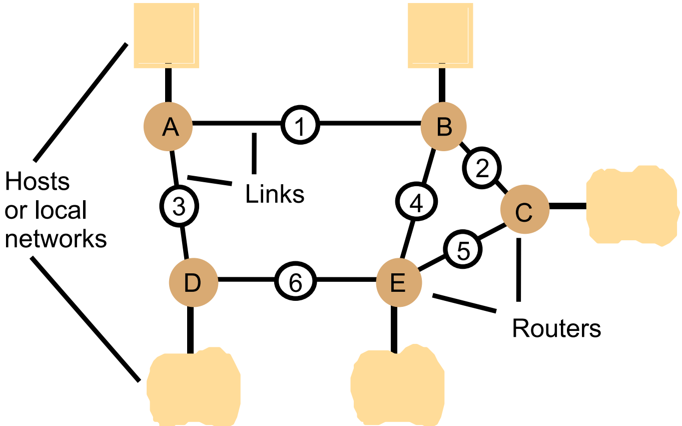
Layer	*Description*	*Examples*
Application	Protocols that are designed to meet the communication requirements of specific applications, often defining the interface to a service.	HTTP,FTP, SMTP, CORBA IIOP
Presentation	Protocols at this level transmit data in a network representation that is independent of the representations used in individual computers, which may differ. Encryption is also performed in this layer, if required.	Secure Sockets (SSL),CORBA Data Rep.
Session	At this level reliability and adaptation are performed, such as detection of failures and automatic recovery.	
Transport	This is the lowest level at which messages (rather than packets) are handled. Messages are addressed to communication ports attached to processes, Protocols in this layer may be connection-oriented or connectionless.	TCP, UDP
Network	Transfers data packets between computers in a specific network. In a WAN or an internetwork this involves the generation of a route passing through routers. In a single LAN no routing is required.	IP, ATM virtual circuits
Data link	Responsible for transmission of packets between nodes that are directly connected by a physical link. In a WAN transmission is between pairs of routers or between routers and hosts. In a LAN it is between any pair of hosts.	Ethernet MAC, ATM cell transfer, PPP
Physical	The circuits and hardware that drive the network. It transmits sequences of binary data by analogue signalling, using amplitude or frequency modulation of electrical signals (on cable circuits), light signals (on fibre optic circuits) or other electromagnetic signals (on radio and microwave circuits).	Ethernet base- band signalling, ISDN

Distributed Systems

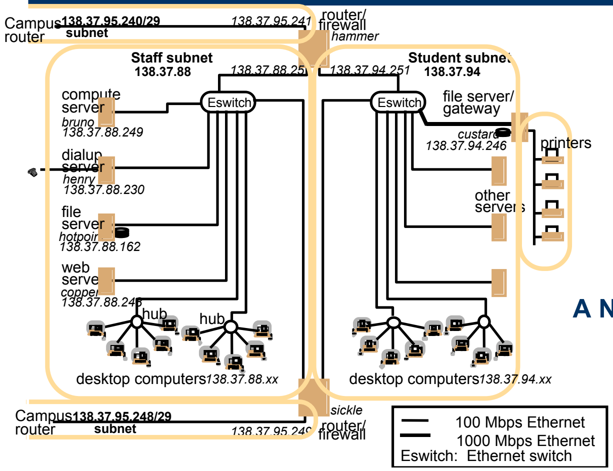


Distributed Systems

Routing in a wide area network

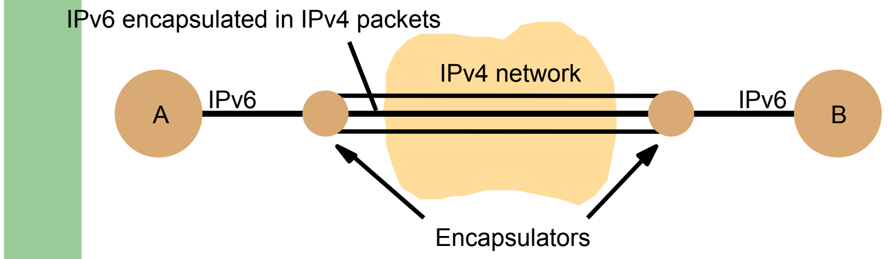


Distributed Systems



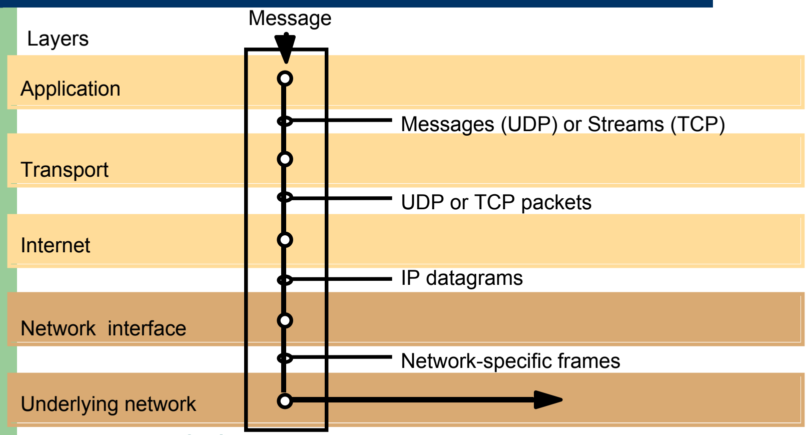
A Network Example

Distributed Systems



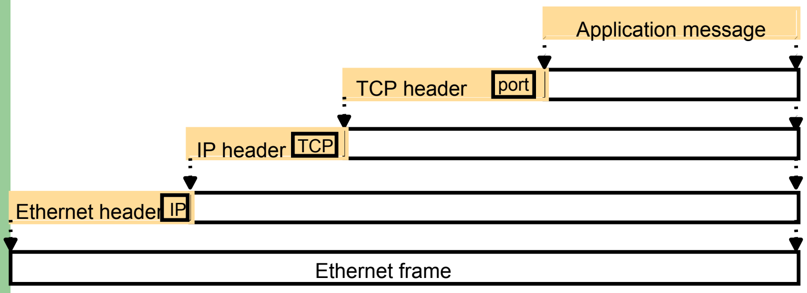
Tunnelling for IPv6 migration

Distributed Systems



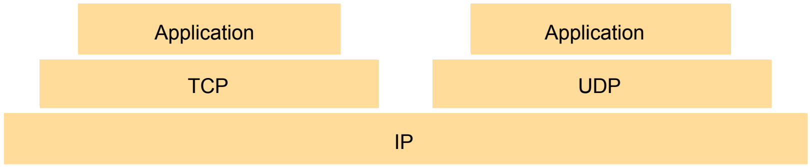
TCP/IP layers

Distributed Systems



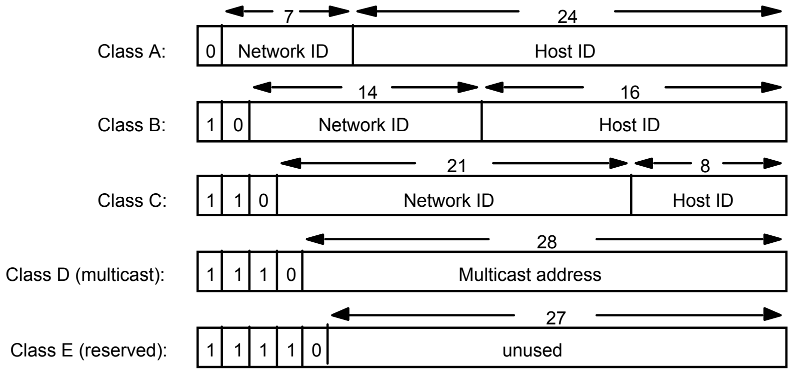
Encapsulation in a message transmitted via TCP over an Ethernet

Distributed Systems



The programmer's conceptual view of a TCP/IP Internet

Distributed Systems



						7	24
Class A:	0					Network ID	Host ID
						14	16
Class B:	1	0				Network ID	Host ID
						21	8
Class C:	1	1	0			Network ID	Host ID
						28	
Class D (multicast):	1	1	1	0		Multicast address	
						27	
Class E (reserved):	1	1	1	1	0	unused	

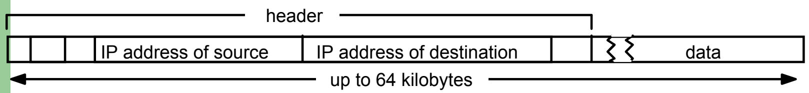
Internet address structure, showing field sizes in bits

Distributed Systems

	octet 1	octet 2	octet 3		Range of addresses
	Network ID		Host ID		
Class A:	1 to 127	0 to 255	0 to 255	0 to 255	1.0.0.0 to 127.255.255.255
	Network ID		Host ID		
Class B:	128 to 191	0 to 255	0 to 255	0 to 255	128.0.0.0 to 191.255.255.255
	Network ID			Host ID	
Class C:	192 to 223	0 to 255	0 to 255	1 to 254	192.0.0.0 to 223.255.255.255
	Multicast address				
Class D (multicast):	224 to 239	0 to 255	0 to 255	1 to 254	224.0.0.0 to 239.255.255.255
Class E (reserved):	240 to 255	0 to 255	0 to 255	1 to 254	240.0.0.0 to 255.255.255.255

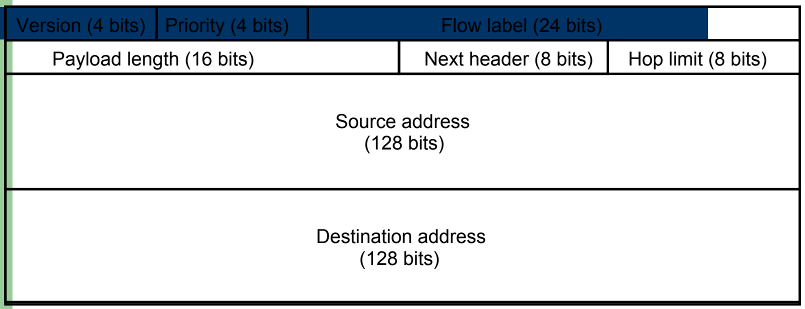
Decimal representation of Internet addresses

Distributed Systems



IP packet layout

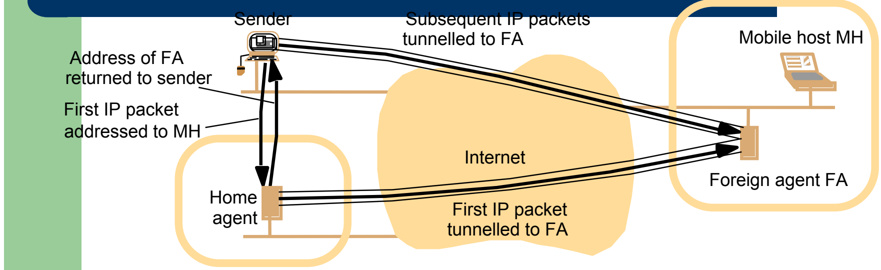
Distributed Systems



Version (4 bits)	Priority (4 bits)	Flow label (24 bits)	
Payload length (16 bits)		Next header (8 bits)	Hop limit (8 bits)
Source address (128 bits)			
Destination address (128 bits)			

IPv6 header layout

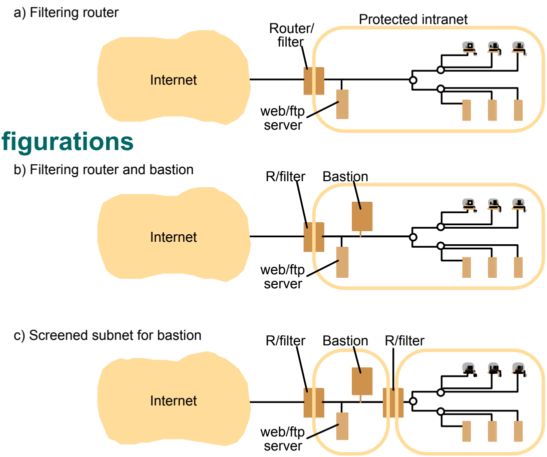
Distributed Systems


Sender
Subsequent IP packets tunnelled to FA
Mobile host MH
Address of FA returned to sender
First IP packet addressed to MH
Internet
Home agent
First IP packet tunnelled to FA
Foreign agent FA

The MobileIP routing mechanism

Distributed Systems

Firewall configurations

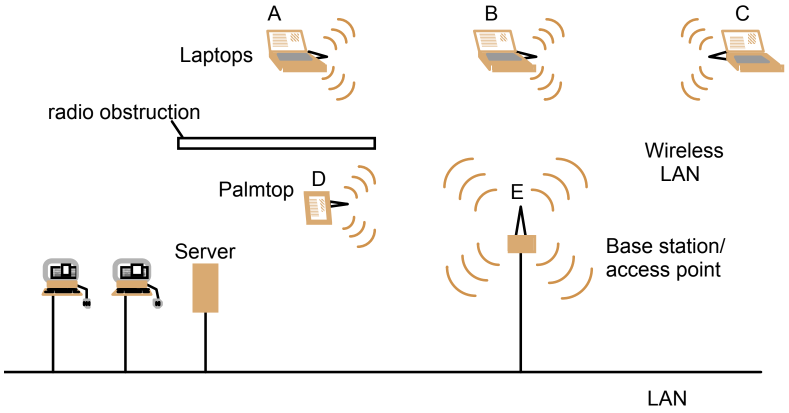


Distributed Systems

IEEE 802 network standards

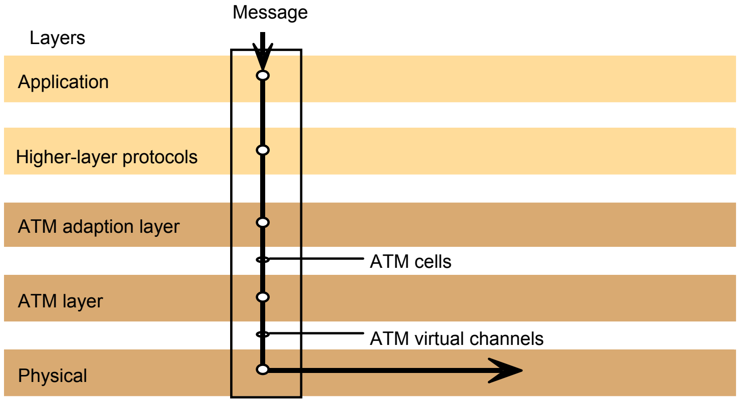
IEEE No.	*Title*	*Reference*
802.3	CSMA/CD Networks (Ethernet)	[IEEE 1985a]
802.4	Token Bus Networks	[IEEE 1985b]
802.5	Token Ring Networks	[IEEE 1985c]
802.6	Metropolitan Area Networks	[IEEE 1994]
802.11	Wireless Local Area Networks	[IEEE 1999]

Distributed Systems



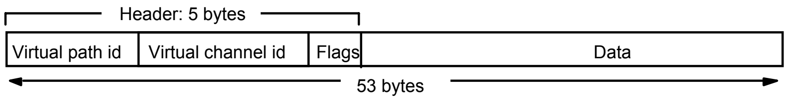
Wireless LAN configuration

Distributed Systems



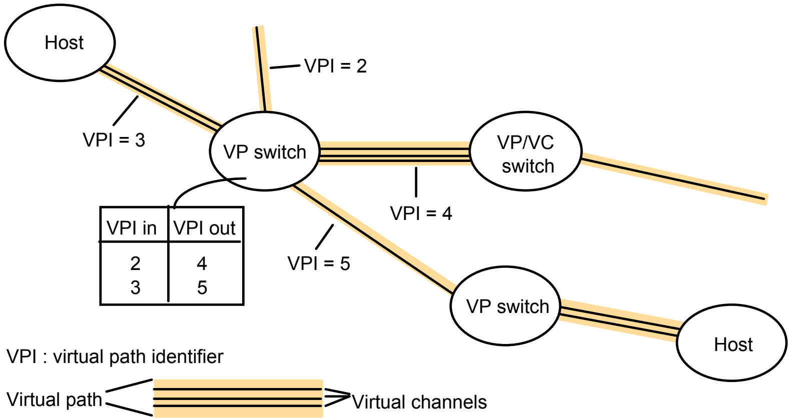
ATM protocol layers

Distributed Systems



ATM cell layout

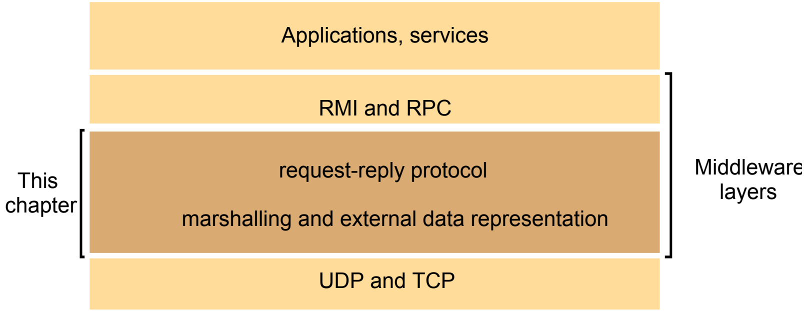
Distributed Systems



VPI in	VPI out
2	4
3	5

Switching virtual paths in an ATM network

Distributed Systems - IPC



Applications, services

RMI and RPC

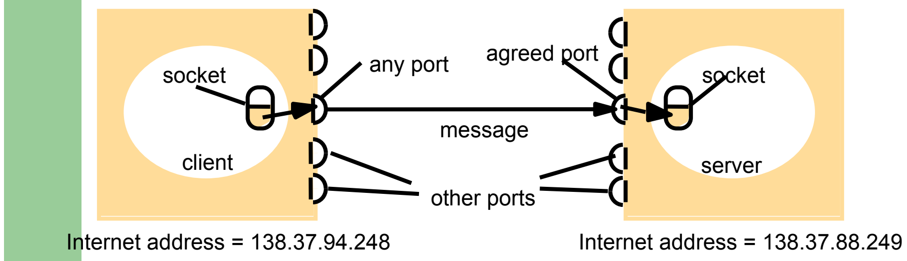
request-reply protocol

marshalling and external data representation

UDP and TCP

Middleware layers

Distributed Systems - IPC


socket
client
any port
agreed port
message
other ports
socket
server
Internet address = 138.37.94.248
Internet address = 138.37.88.249

Sockets and ports

Distributed Systems - IPC

Type	*Representation*
sequence	length (unsigned long) followed by elements in order
string	length (unsigned long) followed by characters in order (can also can have wide characters)
array	array elements in order (no length specified because it is fixed)
struct	in the order of declaration of the components
enumerated	unsigned long (the values are specified by the order declared)
union	type tag followed by the selected member

CORBA CDR for constructed types

Distributed Systems - IPC

index in sequence of bytes	← 4 bytes →	*notes on representation*
0–3	5	*length of string*
4–7	"Smit"	*'Smith'*
8–11	"h___"	
12–15	6	*length of string*
16–19	"Lond"	*'London'*
20-23	"on__"	
24–27	1934	*unsigned long*

The flattened form represents a *Person* struct with value: {'Smith', 'London', 1934}

CORBA CDR message

Distributed Systems - IPC

Serialized values				*Explanation*
Person	8-byte version number		h0	*class name, version number*
3	int year	java.lang.String name:	java.lang.String place:	*number, type and name of instance variables*
1934	5 Smith	6 London	h1	*values of instance variables*

The true serialized form contains additional type markers; h0 and h1 are handles

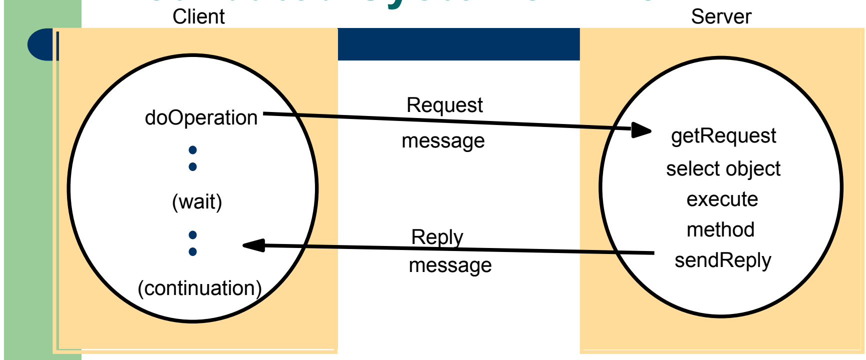
Indication of Java serialized form

Distributed Systems - IPC

32 bits	32 bits	32 bits	32 bits	
Internet address	port number	time	object number	interface of remote object

Representation of a remote object reference

Distributed Systems - IPC



Request-reply communication

Distributed Systems - IPC

public byte[] doOperation (RemoteObjectRef o, int methodId, byte[] arguments)
sends a request message to the remote object and returns the reply.
The arguments specify the remote object, the method to be invoked and the arguments of that method.

public byte[] getRequest ();
acquires a client request via the server port.

public void sendReply (byte[] reply, InetAddress clientHost, int clientPort);
sends the reply message reply to the client at its Internet address and port.

Operations of the request-reply protocol

Distributed Systems - IPC

Request-reply message structure

messageType	*int (0=Request, 1= Reply)*
requestId	*int*
objectReference	*RemoteObjectRef*
methodId	*int or Method*
arguments	*array of bytes*

Distributed Systems - IPC

RPC exchange protocols

Name	*Messages sent by*		
	Client	*Server*	*Client*
R	*Request*		
RR	*Request*	*Reply*	
RRA	*Request*	*Reply*	*Acknowledge reply*

Distributed Systems - IPC

HTTP request message

method	*URL or pathname*	*HTTP version*	*headers*	*message body*
GET	//www.dcs.qmw.ac.uk/index.html	HTTP/ 1.1		

Distributed Systems - IPC

HTTP reply message

HTTP version	*status code*	*reason*	*headers*	*message body*
HTTP/1.1	200	OK		resource data

Distributed Systems - DFS

In this section we will present an important subject in distributed systems, the Distributed File Systems. The idea is to understand how they work And present case study examples.

Therefore, we will :

Distributed Systems - DFS

- Understand the requirements that affect the design of distributed services
- NFS: understand how a relatively simple, widely-used service is designed
  - Obtain a knowledge of file systems, both local and networked
  - Caching as an essential design technique
  - Remote interfaces are not the same as APIs
  - Security requires special consideration
- Recent advances: appreciate the ongoing research that often leads to major advances

Distributed Systems - DFS

- In first generation of distributed systems (1974-95), file systems (e.g. NFS) were the only networked storage systems.
- With the advent of distributed object systems (CORBA, Java) and the web, the picture has become more complex.

Storage systems and their properties

Types of consistency between copies: 1 - strict one-copy consistency
√ - approximate consistency
X - no automatic consistency

Distributed Systems - DFS

	Sharing	*Persis-tence*	*Distributed cache/replicas*	*Consistency maintenance*	*Example*
Main memory	✗	✗	✗	1	RAM
File system	✗	✓	✗	1	UNIX file system
Distributed file system	✓	✓	✓	✓	Sun NFS
Web	✓	✓	✓	✗	Web server
Distributed shared memory	✓	✗	✓	✓	Ivy (Ch. 16)
Remote objects (RMI/ORB)	✓	✗	✗	1	CORBA
Persistent object store	✓	✓	✗	1	CORBA Persistent Object Service
Persistent distributed object store	✓	✓	✓	✓	PerDiS, Khazana

Distributed Systems - DFS

- Persistent stored data sets
- Hierarchic name space visible to all processes
- API with the following characteristics:
  - access and update operations on persistently stored data sets
  - Sequential access model (with additional random facilities)
- Sharing of data between users, with access control
- Concurrent access:
  - certainly for read-only access
  - what about updates?
- Other features:
  - mountable file stores
  - more? ...

WHAT IS A FILE SYSTEM ?

Distributed Systems - DFS

UNIX file system operations

filedes = open(name, mode) *filedes = creat(name, mode)*	Opens an existing file with the given *name*. Creates a new file with the given *name*. Both operations deliver a file descriptor referencing the open file. The *mode* is *read*, *write* or both.
status = close(filedes)	Closes the open file *filedes*.
count = read(filedes, buffer, n) *count = write(filedes, buffer, n)*	Transfers *n* bytes from the file referenced by *filedes* to *buffer*. Transfers *n* bytes to the file referenced by *filedes* from buffer. Both operations deliver the number of bytes actually transferred and advance the read-write pointer.
pos = lseek(filedes, offset, whence)	Moves the read-write pointer to offset (relative or absolute, depending on *whence*).
status = unlink(name)	Removes the file *name* from the directory structure. If the file has no other names, it is deleted.
status = link(name1, name2)	Adds a new name (*name2*) for a file (*name1*).
status = stat(name, buffer)	Gets the file attributes for file *name* into *buffer*.

Distributed Systems - DFS

File system modules

Directory module:	relates file names to file IDs
File module:	relates file IDs to particular files
Access control module:	checks permission for operation requested
File access module:	reads or writes file data or attributes
Block module:	accesses and allocates disk blocks
Device module:	disk I/O and buffering

Distributed Systems - DFS

File attribute record structure

updated by system:	File length
	Creation timestamp
	Read timestamp
	Write timestamp
	Attribute timestamp
	Reference count
updated by owner:	Owner
	File type
	Access control list E.g. for UNIX: `rw-rw-r--`

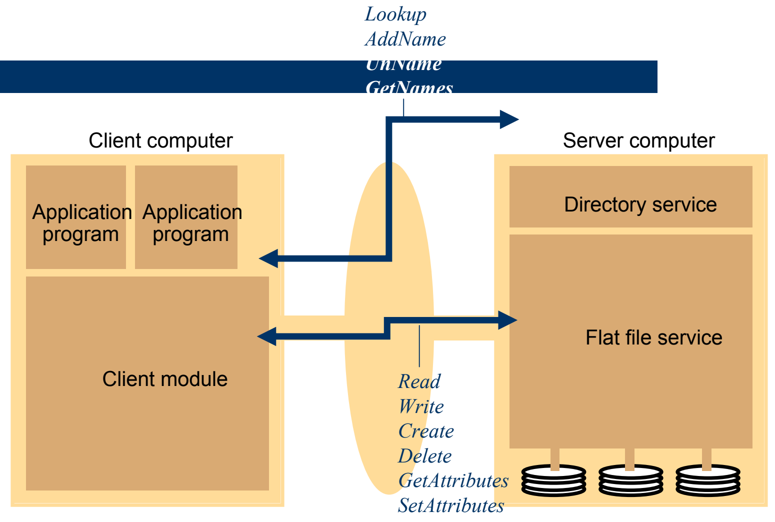
File service requirements

- Transparency
- Concurrency
- Replication
- Heterogeneity
- Fault tolerance
- Consistency
- Security
- Efficiency..

Efficiency

Goal for distributed file systems is usually performance comparable to local file system.

Model file service architecture



File Group

A collection of files that can be located on any server or moved between servers while maintaining the same names.

- Similar to a UNIX *filesystem*
- Helps with distributing the load of file serving between several servers.
- File groups have identifiers which are unique throughout the system (and hence for an open system, they must be globally unique).
  - Used to refer to file groups and files

To construct a globally unique ID we use some unique attribute of the machine on which it is created, e.g. IP number, even though the file group may move subsequently.

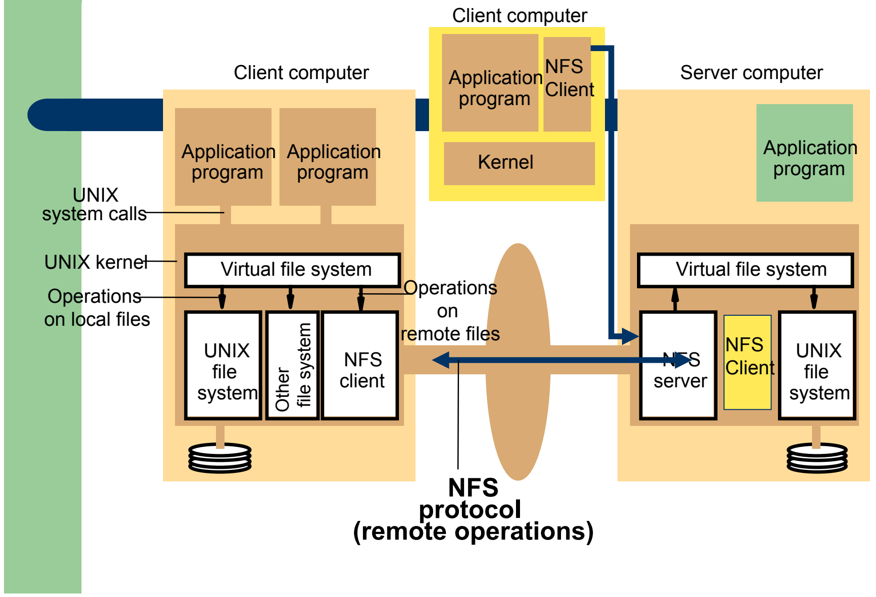
File Group ID:

32 bits	*16 bits*
IP address	date

Case Study: Sun NFS

- An industry standard for file sharing on local networks since the 1980s
- An open standard with clear and simple interfaces
- Closely follows the abstract file service model defined above
- Supports many of the design requirements already mentioned:
  - transparency
  - heterogeneity
  - efficiency
  - fault tolerance
- Limited achievement of:
  - concurrency
  - replication
  - Consistency and security

NFS Architecture



Distributed Systems - DFS

NFS Architecture:
Does the implementation have to be in the system kernel?

No:

– there are examples of NFS clients and servers that run at application-level as libraries or processes (e.g. early Windows and MacOS implementations, current PocketPC, etc.)

*

Distributed Systems - DFS

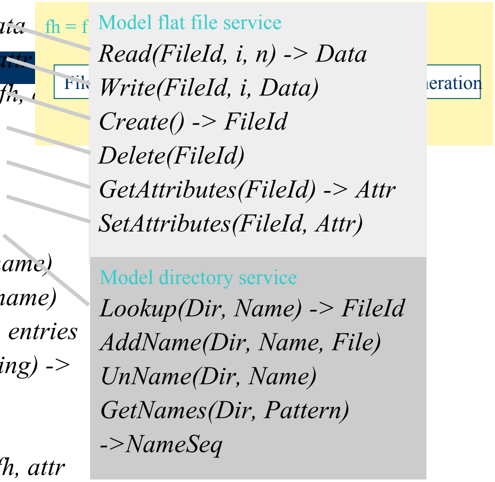
But, for a Unix implementation there are advantages:

– Binary code compatible - no need to recompile applications
  - Standard system calls that access remote files can be routed through the NFS client module by the kernel
– Shared cache of recently-used blocks at client
– Kernel-level server can access i-nodes and file blocks directly
  - but a privileged (root) application program could do almost the same.
– Security of the encryption key used for authentication.

*

NFS server operations (simplified)

- *read(fh, offset, count) -> attr, data*
- *write(fh, offset, count, data) -> attr*
- *create(dirfh, name, attr) -> newfh,*
- *remove(dirfh, name) status*
- *getattr(fh) -> attr*
- *setattr(fh, attr) -> attr*
- *lookup(dirfh, name) -> fh, attr*
- *rename(dirfh, name, todirfh, toname)*
- *link(newdirfh, newname, dirfh, name)*
- *readdir(dirfh, cookie, count) -> entries*
- *symlink(newdirfh, newname, string) -> status*
- *readlink(fh) -> string*
- *mkdir(dirfh, name, attr) -> newfh, attr*
- *rmdir(dirfh, name) -> status*
- *statfs(fh) -> fsstats*



Model flat file service

Read(FileId, i, n) -> Data
Write(FileId, i, Data)
Create() -> FileId
Delete(FileId)
GetAttributes(FileId) -> Attr
SetAttributes(FileId, Attr)

Model directory service

Lookup(Dir, Name) -> FileId
AddName(Dir, Name, File)
UnName(Dir, Name)
GetNames(Dir, Pattern) ->NameSeq

*

NFS access control and authentication

- Stateless server, so the user's identity and access rights must be checked by the server on each request.
  – In the local file system they are checked only on *open()*
- Every client request is accompanied by the userID and groupID
  – not shown in the Figure 8.9 because they are inserted by the RPC system
- Server is exposed to imposter attacks unless the userID and groupID are protected by encryption
- Kerberos has been integrated with NFS to provide a stronger and more comprehensive security solution
  – Kerberos is described in Chapter 7. Integration of NFS with Kerberos is covered later in this chapter.

*

Mount service

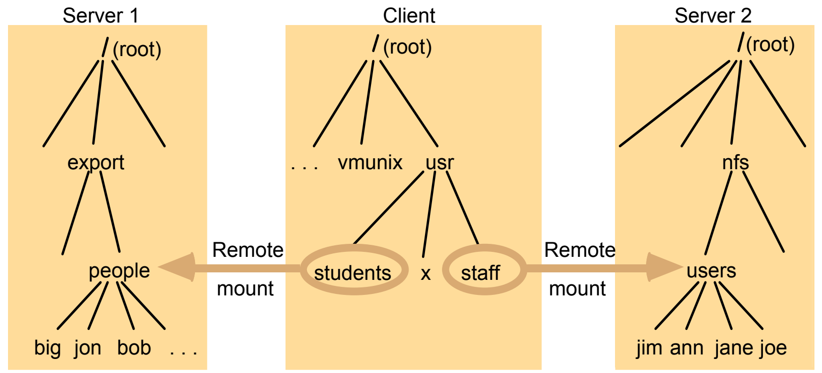
- Mount operation:

  mount(remotehost, remotedirectory, localdirectory)
- Server maintains a table of clients who have mounted filesystems at that server
- Each client maintains a table of mounted file systems holding:

  < IP address, port number, file handle>
- *Hard* versus *soft* mounts

*

Local and remote file systems accessible on an NFS client



Note: The file system mounted at */usr/students* in the client is actually the sub-tree located at */export/people* in Server 1; the file system mounted at */usr/staff* in the client is actually the sub-tree located at */nfs/users* in Server 2.

*

Automounter

NFS client catches attempts to access 'empty' mount points and routes them to the Automounter

- Automounter has a table of mount points and multiple candidate serves for each
- it sends a probe message to each candidate server and then uses the mount service to mount the filesystem at the first server to respond

- Keeps the mount table small
- Provides a simple form of replication for read-only filesystems
  - E.g. if there are several servers with identical copies of /usr/lib then each server will have a chance of being mounted at some clients.

*

Kerberized NFS

- Kerberos protocol is too costly to apply on each file access request
- Kerberos is used in the mount service:
  - to authenticate the user's identity
  - User's UserID and GroupID are stored at the server with the client's IP address
- For each file request:
  - The UserID and GroupID sent must match those stored at the server
  - IP addresses must also match
- This approach has some problems
  - can't accommodate multiple users sharing the same client computer
  - all remote filestores must be mounted each time a user logs in

*

NFS optimization - server caching

- Similar to UNIX file caching for local files:
  - pages (blocks) from disk are held in a main memory buffer cache until the space is required for newer pages. Read-ahead and delayed-write optimizations.
  - For local files, writes are deferred to next sync event (30 second intervals)
  - Works well in local context, where files are always accessed through the local cache, but in the remote case it doesn't offer necessary synchronization guarantees to clients.

NFS optimization - server caching

- NFS v3 servers offers two strategies for updating the disk:
  - *write-through* - altered pages are written to disk as soon as they are received at the server. When a *write()* RPC returns, the NFS client knows that the page is on the disk.
  - *delayed commit* - pages are held only in the cache until a *commit()* call is received for the relevant file. This is the default mode used by NFS v3 clients. A *commit()* is issued by the client whenever a file is closed.

NFS optimization - client caching

- Server caching does nothing to reduce RPC traffic between client and server
  - further optimization is essential to reduce server load in large networks
  - NFS client module caches the results of *read*, *write*, *getattr*, *lookup* and *readdir* operations
  - synchronization of file contents (*one-copy semantics*) is not guaranteed when two or more clients are sharing the same file.

NFS optimization - client caching

- Timestamp-based validity check
  - reduces inconsistency, but doesn't eliminate it
  - validity condition for cache entries at the client:

    $(T - Tc < t) \vee (Tm_{client} = Tm_{server})$
  - *t* is configurable (per file) but is typically set to 3 seconds for files and 30 secs. for directories
  - it remains difficult to write distributed applications that share files with NFS

t	freshness guarantee
Tc	time when cache entry was last validated
Tm	time when block was last updated at server
T	current time

Other NFS optimizations

- Sun RPC runs over UDP by default (can use TCP if required)
- Uses UNIX BSD Fast File System with 8-kbyte blocks
- *reads()* and *writes()* can be of any size (negotiated between client and server)
- the guaranteed freshness interval *t* is set adaptively for individual files to reduce *gettattr()* calls needed to update *Tm*
- file attribute information (including *Tm*) is piggybacked in replies to all file requests

NFS performance

- Early measurements (1987) established that:
  - *write()* operations are responsible for only 5% of server calls in typical UNIX environments
    - hence write-through at server is acceptable
  - *lookup()* accounts for 50% of operations -due to step-by-step pathname resolution necessitated by the naming and mounting semantics.

NFS performance

- More recent measurements (1993) show high performance:

  1 x 450 MHz Pentium III: > 5000 server ops/sec, < 4 millisec. average latency

  24 x 450 MHz IBM RS64: > 29,000 server ops/sec, < 4 millisec. average latency

  see www.spec.org for more recent measurements

NFS performance

- Provides a good solution for many environments including:
  - large networks of UNIX and PC clients
  - multiple web server installations sharing a single file store

NFS - Summary

- An excellent example of a simple, robust, high-performance distributed service.
- Achievement of transparencies :

Access: *Excellent*; the API is the UNIX system call interface for both local and remote files.

Location: *Not guaranteed but normally achieved*; naming of filesystems is controlled by client mount operations, but transparency can be ensured by an appropriate system configuration.

NFS - Summary

Concurrency: *Limited but adequate for most purposes*; when read-write files are shared concurrently between clients, consistency is not perfect.

Replication: *Limited to read-only file systems*; for writable files, the SUN Network Information Service (NIS) runs over NFS and is used to replicate essential system files.

NFS - Summary

Achievement of transparencies (continued):

Failure: *Limited but effective*; service is suspended if a server fails. Recovery from failures is aided by the simple stateless design.

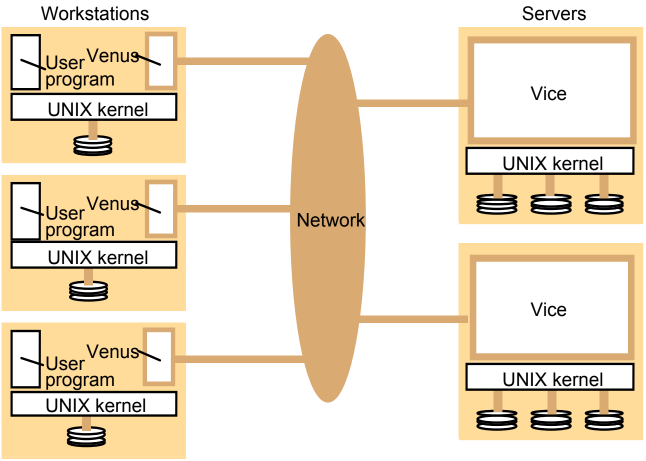
Mobility: *Hardly achieved*; relocation of files is not possible, relocation of file systems is possible, but requires updates to client configurations.

NFS - Summary

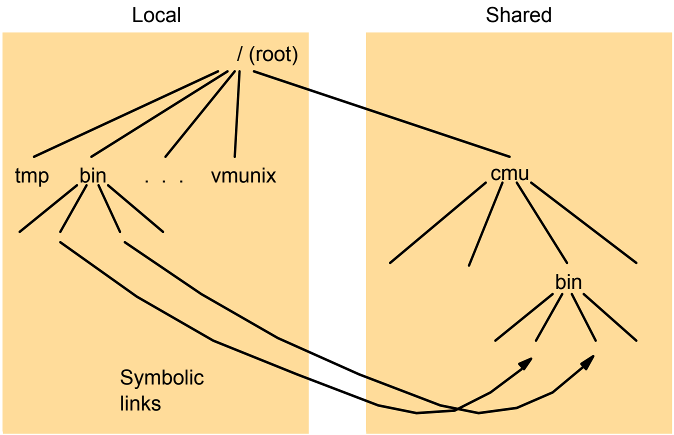
Performance: *Good*; multiprocessor servers achieve very high performance, but for a single filesystem it's not possible to go beyond the throughput of a multiprocessor server.

Scaling: *Good*; filesystems (file groups) may be subdivided and allocated to separate servers. Ultimately, the performance limit is determined by the load on the server holding the most heavily-used filesystem (file group).

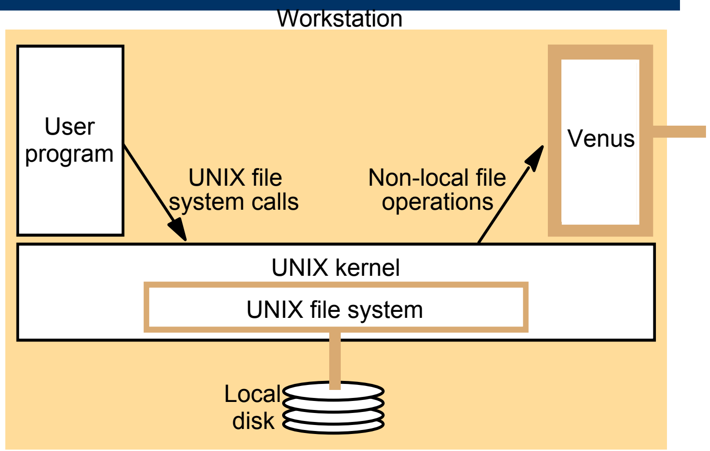
Distribution of processes in the Andrew File System



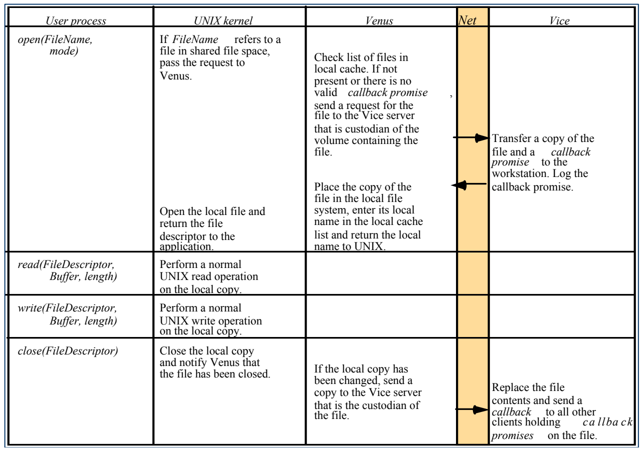
File name space seen by clients of AFS



System call interception in AFS



Implementation of file system calls in AFS



User process	*UNIX kernel*	*Venus*	*Net*	*Vice*
open(FileName, mode)	If *FileName* refers to a file in shared file space, pass the request to Venus. Open the local file and return the file descriptor to the application.	Check list of files in local cache. If not present or there is no valid *callback promise*, send a request for the file to the Vice server that is custodian of the volume containing the file. Place the copy of the file in the local file system, enter its local name in the local cache list and return the local name to UNIX.	→ ←	Transfer a copy of the file and a *callback promise* to the workstation. Log the callback promise.
read(FileDescriptor, Buffer, length)	Perform a normal UNIX read operation on the local copy.			
write(FileDescriptor, Buffer, length)	Perform a normal UNIX write operation on the local copy.			
close(FileDescriptor)	Close the local copy and notify Venus that the file has been closed.	If the local copy has been changed, send a copy to the Vice server that is the custodian of the file.	→	Replace the file contents and send a *callback* to all other clients holding *ca llba ck promises* on the file.

The main components of the Vice service interface

Fetch(fid) -> attr, data	Returns the attributes (status) and, optionally, the contents of file identified by the *fid* and records a callback promise on it.
Store(fid, attr, data)	Updates the attributes and (optionally) the contents of a specified file.
Create() -> fid	Creates a new file and records a callback promise on it.
Remove(fid)	Deletes the specified file.
SetLock(fid, mode)	Sets a lock on the specified file or directory. The mode of the lock may be shared or exclusive. Locks that are not removed expire after 30 minutes.
ReleaseLock(fid)	Unlocks the specified file or directory.
RemoveCallback(fid)	Informs server that a Venus process has flushed a file from its cache.
BreakCallback(fid)	This call is made by a Vice server to a Venus process. It cancels the callback promise on the relevant file.

Recent advances in file services

NFS enhancements

WebNFS - NFS server implements a web-like service on a well-known port. Requests use a 'public file handle' and a pathname-capable variant of *lookup()*. Enables applications to access NFS servers directly, e.g. to read a portion of a large file.

One-copy update semantics (Spritely NFS, NQNFS) - Include an *open()* operation and maintain tables of open files at servers, which are used to prevent multiple writers and to generate callbacks to clients notifying them of updates. Performance was improved by reduction in *gettattr()* traffic.

Recent advances in file services

Improvements in disk storage organisation

RAID - improves performance and reliability by striping data redundantly across several disk drives

Log-structured file storage - updated pages are stored contiguously in memory and committed to disk in large contiguous blocks (~ 1 Mbyte). File maps are modified whenever an update occurs. Garbage collection to recover disk space.

New design approaches

Distribute file data across several servers

- Exploits high-speed networks (ATM, Gigabit Ethernet)
- Layered approach, lowest level is like a 'distributed virtual disk'
- Achieves scalability even for a single heavily-used file

'Serverless' architecture

- Exploits processing and disk resources in all available network nodes
- Service is distributed at the level of individual files

New design approaches

Examples:

xFS : Experimental implementation demonstrated a substantial performance gain over NFS and AFS

Frangipani : Performance similar to local UNIX file access

Tiger Video File System

Peer-to-peer systems: Napster, OceanStore (UCB), Farsite (MSR), Publius (AT&T research) - see web for documentation on these very recent systems

New design approaches

- Replicated read-write files
  - High availability
  - Disconnected working
    - re-integration after disconnection is a major problem if conflicting updates have occurred
  - Examples:
    - Bayou system
    - Coda system

Summary

- Sun NFS is an excellent example of a distributed service designed to meet many important design requirements
- Effective client caching can produce file service performance equal to or better than local file systems
- Consistency *versus* update semantics *versus* fault tolerance remains an issue

Summary

- Most client and server failures can be masked
- Superior scalability can be achieved with whole-file serving (Andrew FS) or the distributed virtual disk approach

Future requirements:

- support for mobile users, disconnected operation, automatic re-integration (Cf. Coda file system)
- support for data streaming and quality of service (Cf. Tiger file system)

Distributed Systems – Names Services

The objectives of this section are –

- To understand the need for naming systems in distributed systems
- To be familiar with the design requirements for distributed name services
- To understand the operation of the Internet naming service - DNS
- To be familiar with the role of discovery services in mobile and ubiquitous computer systems

The role of names and name services

- Resources are accessed using *identifier* or *reference*
  - An identifier can be stored in variables and retrieved from tables quickly
  - Identifier includes or can be transformed to an address for an object
    - E.g. NFS file handle, Corba remote object reference
  - A *name* is human-readable value (usually a string) that can be *resolved* to an identifier or address
    - Internet domain name, file pathname, process number
    - E.g ./etc/passwd, http://www.cdk3.net/

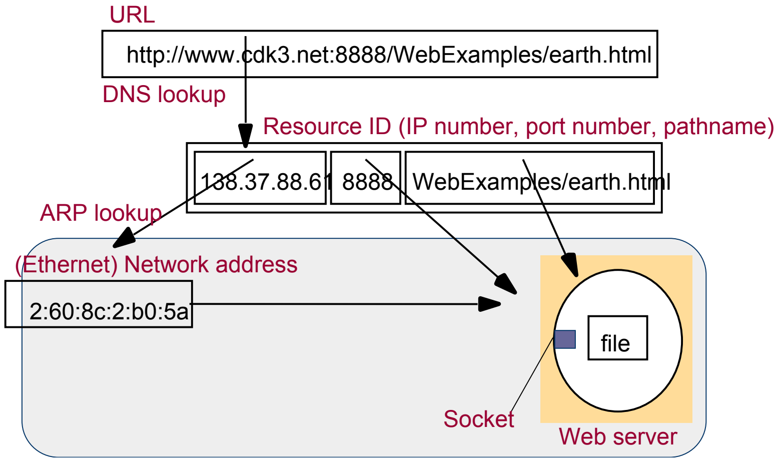
The role of names and name services

- For many purposes, names are preferable to identifiers
  - because the binding of the named resource to a physical location is deferred and can be changed
  - because they are more meaningful to users
- Resource names are *resolved* by name services
  - to give identifiers and other useful attributes

Requirements for name spaces

- Allow simple but meaningful names to be used
- Potentially infinite number of names
- Structured
  - to allow similar subnames without clashes
  - to group related names
- Allow re-structuring of name trees
  - for some types of change, old programs should continue to work
- Management of trust

Composed naming domains used to access a resource from a URL



URL
http://www.cdk3.net:8888/WebExamples/earth.html
DNS lookup
Resource ID (IP number, port number, pathname)
138.37.88.61
8888
WebExamples/earth.html
ARP lookup
(Ethernet) Network address
2:60:8c:2:b0:5a
file
Socket
Web server

*

Names and resources

Currently, different name systems are used for each type of resource:

resource	*name*	*identifies*
file	pathname	file within a given file system
process	process id	process on a given computer
port	port number	IP port on a given computer

Uniform Resource Identifiers (URI) offer a general solution for any type of resource. There two main classes:

URL Uniform Resource Locator

- typed by the protocol field (http, ftp, nfs, etc.)
- part of the name is service-specific
- resources cannot be moved between domains

URN Uniform Resource Name

- requires a universal resource name lookup service - a DNS-like system for all resources

*

Names and resources

More on URNs

format: *urn:<nameSpace>:<name-within-namespace>*

examples:

a) *urn:ISBN:021-61918-0*

b) *urn:dcs.qmul.ac.uk:TR2000-56*

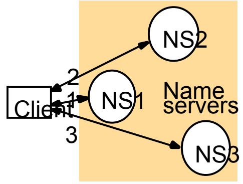
resolution:

a) *send a request to nearest ISBN-lookup service - it would return whatever attributes of a book are required by the requester*

b) *send a request to the urn lookup service at dcs.qmul.ac.uk - it would return a url for the relevant document*

*

Iterative navigation



A client iteratively contacts name servers NS1–NS3 in order to resolve a name

*

Iterative navigation

Reason for NFS iterative name resolution
This is because the file service may encounter a symbolic link (i.e. an *alias*) when resolving a name. A symbolic link must be interpreted in the client's file system name space because it may point to a file in a directory stored at another server. The client computer must determine which server this is, because only the client knows its mount points. (p.362.)

Iterative navigation

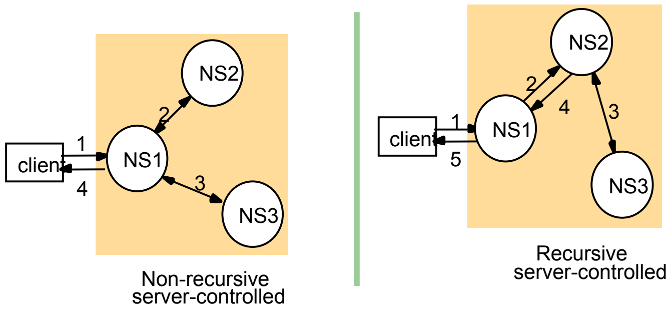
Used in:

DNS: Client presents entire name to servers, starting at a local server, NS1. If NS1 has the requested name, it is resolved, else NS1 suggests contacting NS2 (a server for a domain that includes the requested name).

NFS: Client segments pathnames (into 'simple names') and presents them one at a time to a server together with the filehandle of the directory that contains the simple name.

*

Non-recursive and recursive server-controlled navigation



Non-recursive server-controlled

Recursive server-controlled

A name server NS1 communicates with other name servers on behalf of a client

*

Non-recursive and recursive server-controlled navigation

DNS offers recursive navigation as an option, but iterative is the standard technique. Recursive navigation must be used in domains that limit client access to their DNS information for security reasons.

*

DNS - The Internet Domain Name System

- A distributed naming database
- Name structure reflects administrative structure of the Internet
- Rapidly resolves domain names to IP addresses
  - exploits caching heavily
  - typical query time ~100 milliseconds
- Scales to millions of computers
  - partitioned database
  - caching
- Resilient to failure of a server
  - replication

*

DNS - The Internet Domain Name System

Basic DNS algorithm for name resolution (domain name -> IP number)

- Look for the name in the local cache
- Try a superior DNS server, which responds with:
  - another recommended DNS server
  - the IP address (which may not be entirely up to date)

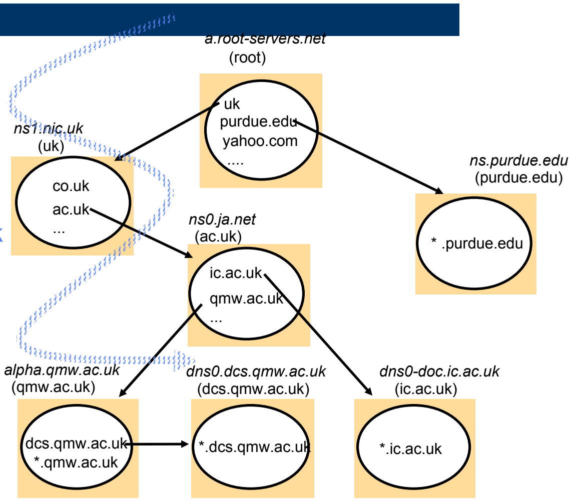
*

DNS name servers

Note: Name server names are in italics, and the corresponding domains are in parentheses. Arrows denote name server entries

authoritative path to lookup:

jeans-pc.dcs.qmw.ac.uk



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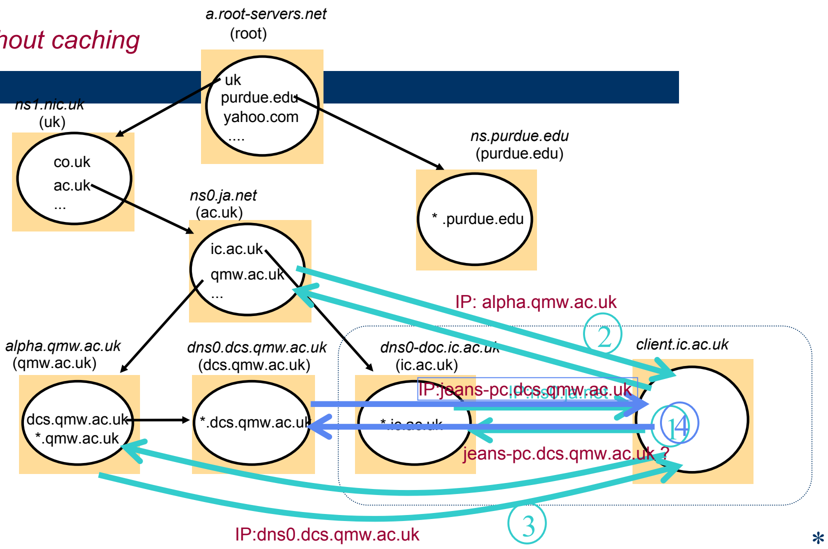
Without caching



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DNS server functions and configuration

- Main function is to resolve domain names for computers, i.e. to get their IP addresses
  - caches the results of previous searches until they pass their 'time to live'
- Other functions:
  - get *mail host* for a domain
  - reverse resolution - get domain name from IP address
  - Host information - type of hardware and OS
  - Well-known services - a list of well-known services offered by a host
  - Other attributes can be included (optional)

DNS resource records

Record type	*Meaning*	*Main contents*
A	A computer address	IP number
NS	An authoritative name server	Domain name for server
CNAME	The canonical name for an alias	Domain name for alias
SOA	Marks the start of data for a zone	Parameters governing the zone
WKS	A well-known service description	List of service names and protocols
PTR	Domain name pointer (reverse lookups)	Domain name
HINFO	Host information	Machine architecture and operating system
MX	Mail exchange	List of <*preference, host*> pairs
TXT	Text string	Arbitrary text

DNS issues

- Name tables change infrequently, but when they do, caching can result in the delivery of stale data.
  - Clients are responsible for detecting this and recovering
- Its design makes changes to the structure of the name space difficult. For example:
  - merging previously separate domain trees under a new root
  - moving subtrees to a different part of the structure (e.g. if Scotland became a separate country, its domains should all be moved to a new country-level domain.

The GNS, is a research system that solves the above issues.

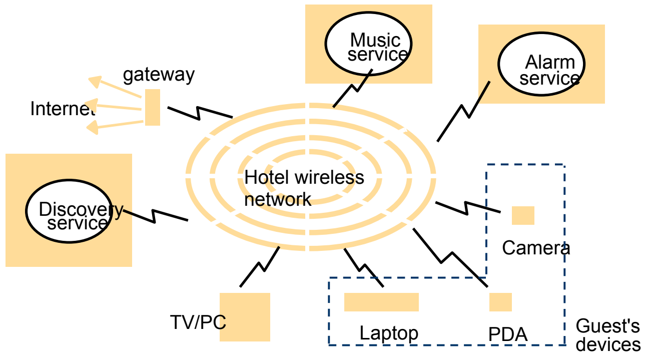
Directory and discovery services

- Directory service:- 'yellow pages' for the resources in a network
  - Retrieves the set of names that satisfy a given description
  - e.g. X.500, LDAP, MS Active Directory Services
    - (DNS holds some descriptive data, but:
      - the data is very incomplete
      - DNS isn't organised to search it)

Directory and discovery services

- Discovery service:- a directory service that also:
  - is automatically updated as the network configuration changes
  - meets the needs of clients in spontaneous networks (Section 2.2.3)
  - discovers services required by a client (who may be mobile) within the current *scope*, for example, to find the most suitable printing service for image files after arriving at a hotel.
  - *Examples of discovery services*: Jini discovery service, the 'service location protocol', the 'simple service discovery protocol' (part of UPnP), the 'secure discovery service'.

Revision: Spontaneous networks



Revision: Spontaneous networks

- Easy connection of guest's devices
  - wireless network
  - automatic configuration
- Easy integration with local services
  - discovery of services relevant to guest's needs

Revision: Spontaneous networks

Discovery service

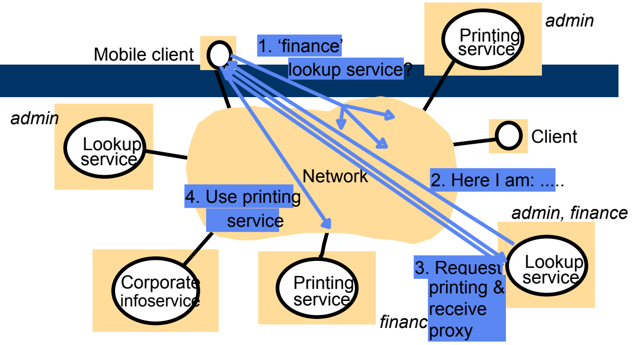
- .A database of services with lookup based on service description or type, location and other criteria, E.g.
  1. Find a printing service in this hotel compatible with a Nikon camera
  2. Send the video from my camera to the digital TV in my room.
- Automatic registration of new services
- Automatic connection of guest's clients to the discovery service

Revision: Spontaneous networks

Other issues for spontaneous networking:

- Unreliable connections when mobile
- Security exposure of ports and communication channels

*



Service discovery in Jini

*

Service discovery in Jini

- Jini services register their interfaces and descriptions with the Jini *lookup* services in their scope
- Clients find the Jini lookup services in their scope by IP multicast
- Jini *lookup* service searches by attribute or by *interface type*
  - The designers of Jini argue convincingly that this the only reliable way to do discovery

*

Topics not covered

- GNS case study
  - an early research project (1985) that developed solutions for the problems of:
    - large name spaces
    - restructuring the name space
- X.500 and LDAP
  - a hierarchically-structured standard directory service designed for world-wide use
  - accommodates resource descriptions in a standard form and their retrieval for any resource (online or offline)
  - never fully deployed, but the standard forms the basis for LDAP, the Lightweight Directory Access Protocol, which is widely used

*

Topics not covered

- Trading services
  - Directories of services with retrieval by attribute searching
  - Brokers negotiate the contract for the use of a service, including negotiation of attribute such as quality and quantity of service

Summary

Name services:

- defer the binding of resource names to addresses (and other attributes)
- Names are resolved to give addresses and other attributes
- Goals :
  - Scalability (size of database, access traffic (hits/second), update traffic)
  - Reliability
  - Trust management (authority of servers)
- Issues
  - exploitation of replication and caching to achieve scalability without compromising the distribution of updates
  - navigation methods

Summary

Directory and discovery services:

- 'yellow pages' retrieval by attributes
- dynamic resource registration and discovery

Questions ?

End of Part I (Distributed Systems)

Course Outline

- Distributed Systems
- High Performance Networks
- Clusters and Computational Grids

Course Outline

High-Performance Networks

Networks become the important part to any system, because nowadays distributed local and remote systems are the bases of any computational environment. However, different network approaches exists.

In this module of the course we will study high performance networks.

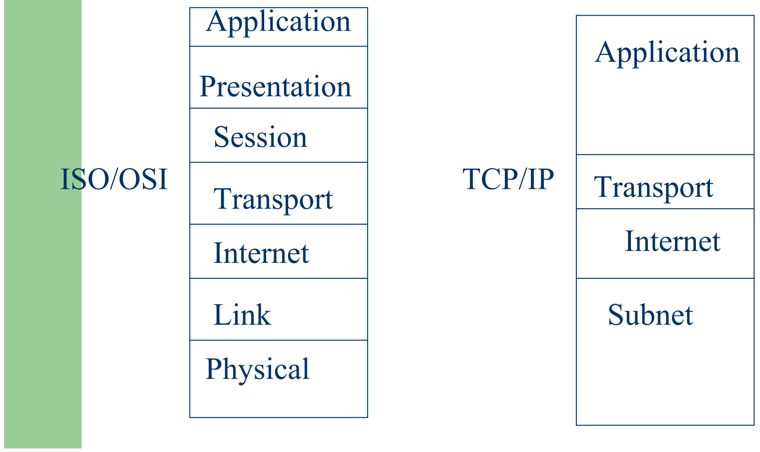
Course Outline

The recommended literature are presented below :

- *Tecnologias de Redes de Comunicação e Computadores,* ***Mario Dantas,*** Axcel Books, ISBN 85-7323-169-6
- *High Performance Networks - Technology and Protocols* (Editor)**Ahmed N. Tantawy**, Kluwer, ISBN 0-7923-9371-6;
- *Sharing Bandwidth*, **Simon St. Laurent**, IDG Books, ISBN 0-7645-7009-9;
- 4 - *Internetworking with TCP/IP - Volume I Principles, Protocols, and Architecture,* **Douglas E. Comer**, Third Edition, Prentice Hall, 1995, ISBN 0-13-216987-8;

ISO/OSI Model and TCP/IP Architecture

High Performance Networks



ISO/OSI

Application

Presentation

Session

Transport

Internet

Link

Physical

TCP/IP

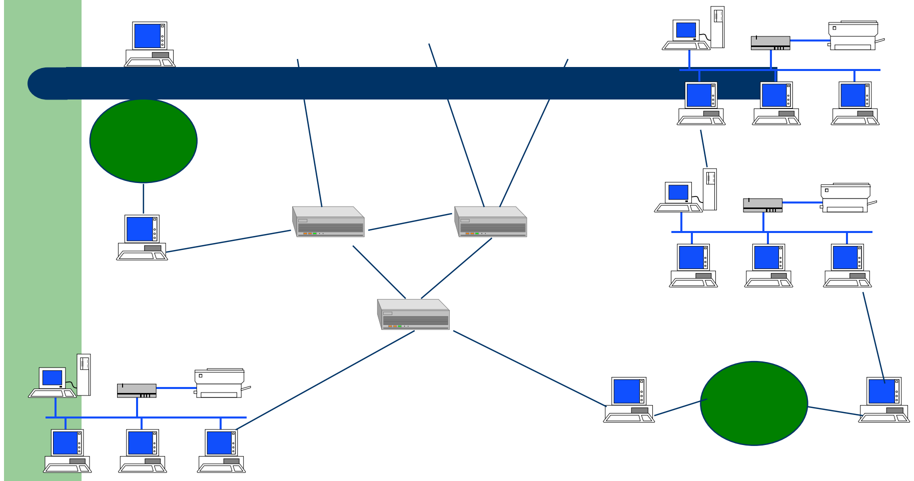
Application

Transport

Internet

Subnet

Internet



Internet Architecture

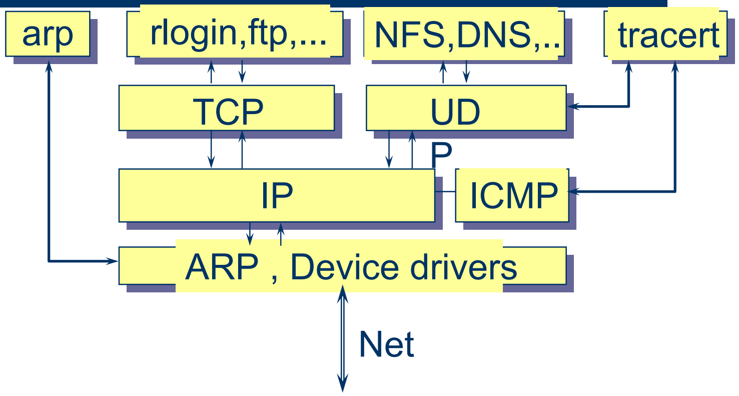
FTP, TELNET, SMTP, DNS, SNMP

TCP UDP

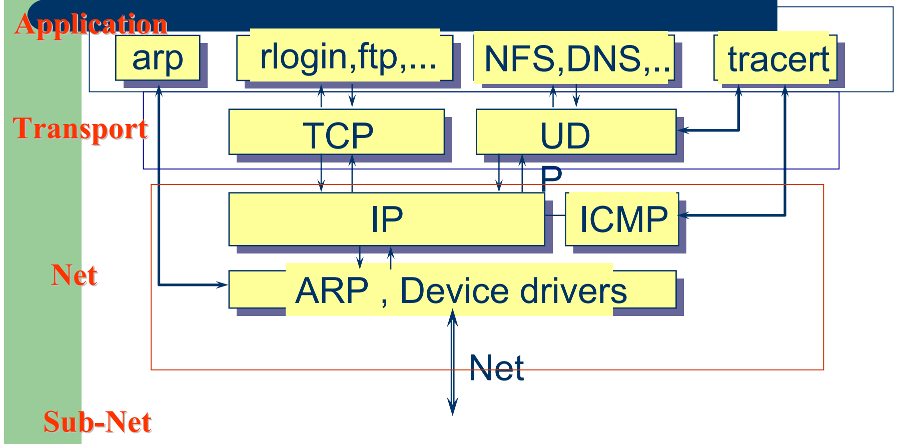
IP, ICMP, ARP, RARP

Sub-net access

TCP/IP Protocol Family

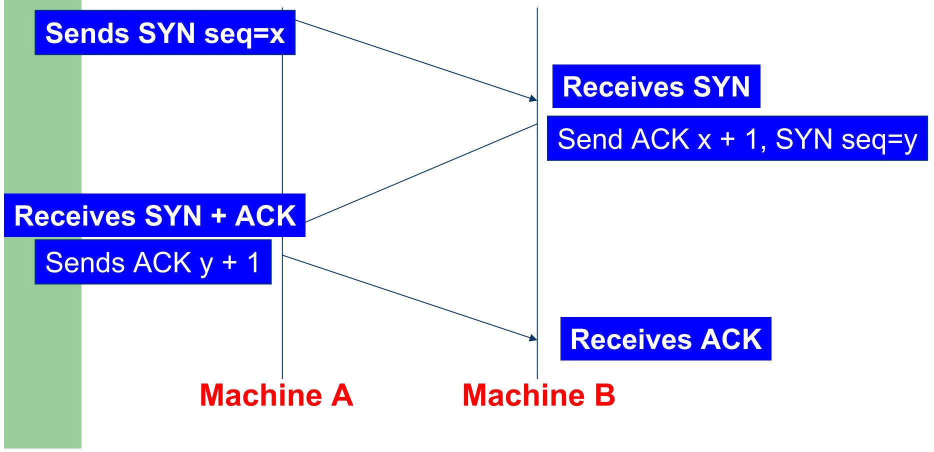


TCP/IP Protocol Family



High Performance Networks

TCP - Connection



Sends SYN seq=x

Receives SYN

Send ACK x + 1, SYN seq=y

Receives SYN + ACK

Sends ACK y + 1

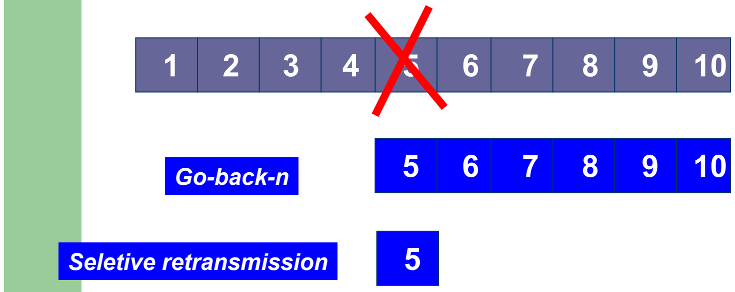
Receives ACK

Machine A

Machine B

TCP - Acknowledgement and retransmission

Go-back-n x seletive retransmission



1	2	3	4	~~5~~	6	7	8	9	10

Go-back-n

5	6	7	8	9	10

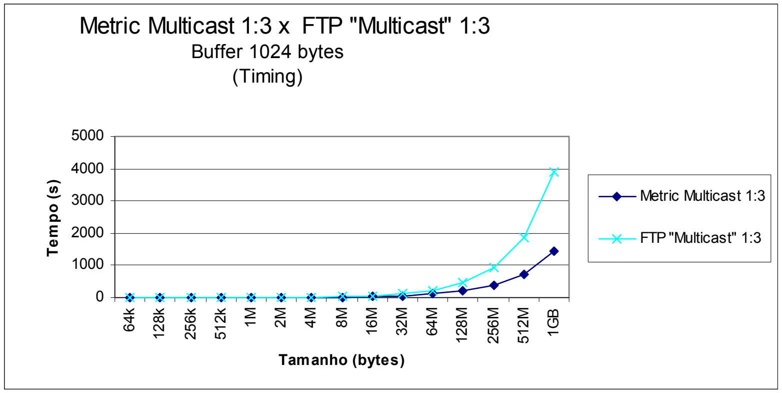
Seletive retransmission

5

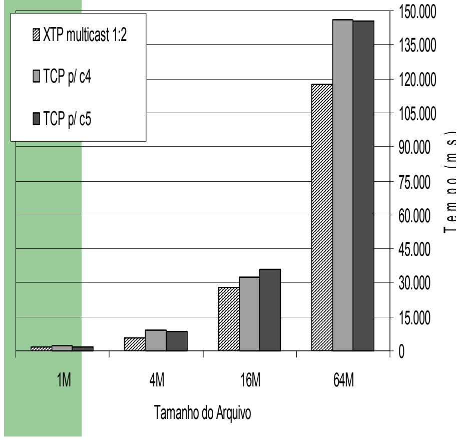
High Performance Networks

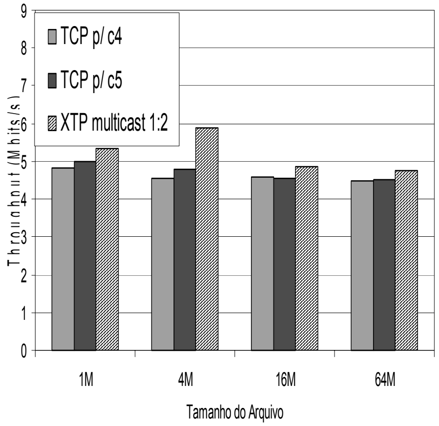
Lightweight Protocols

High Performance Networks

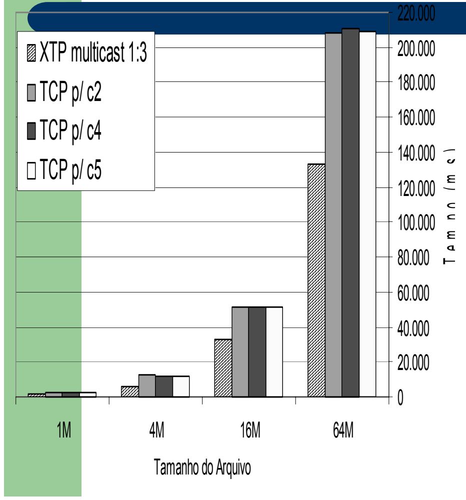


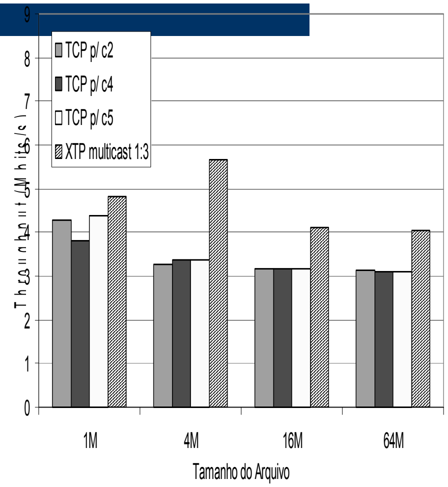
High Performance Networks



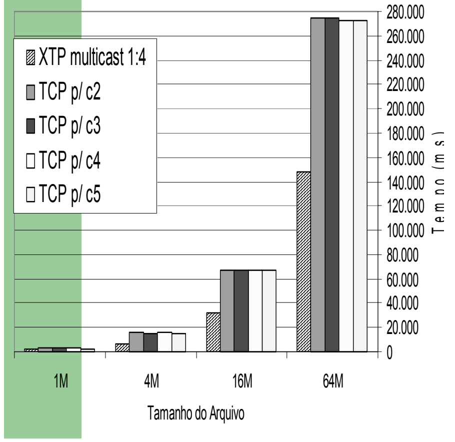


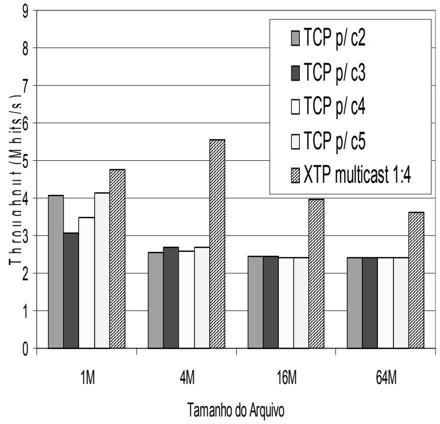
High Performance Networks





High Performance Networks





Questions ?

End of Part II
(High Performance Networks)

Course Outline

- Distributed Systems
- High Performance Networks
- Clusters and Computational Grids

Course Outline

- Computing Paradigms and Applications
- Users
- Grid Architecture
- Grid Computing Environments
- Experimental Results

Course Outline

The recommended literature for this part of the course is :

- *The Grid : Blueprint for a New Computing Infrastructure*, Foster,I. , Kesselman, C.
  Morgan Kaufmann, 1998, ISBN 1558604758.
- *Grid Computing: Making The Global Infrastructure a Reality,* Berman, F., Fox, G., Hey, T. , John Wiley & Sons, 2003, ISBN 0470853190.

Clusters and Computational Grids

What is the difference between Cluster and Computational Grid ?

Computing Paradigms and Applications

A important difference between clusters and grids is mainly based in the way *resources are managed*.

In the clusters, the resource allocation is performed by a centralized resource manager and all nodes cooperatively work together as *a single unified resource.*

Inside the Grids, each node has its own resource manager and do *not target* for providing *a single system view.*

Clusters

High Performance Computing (HPC) traditionally has been based on specific parallel architectures, such as MPP (Massively Parallel Processors) and SMP (Symmetric Memory Processors)

More recently, low cost computers gather either physically or virtually, are used called as *Clusters* or *Nows*. These architectures are interesting to many organizations.

Clusters

What is a cluster configuration ?

1997 GORDON BELL PRIZE

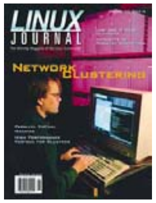
Winner

[illegible]

Winner

[illegible]

COMPUTER



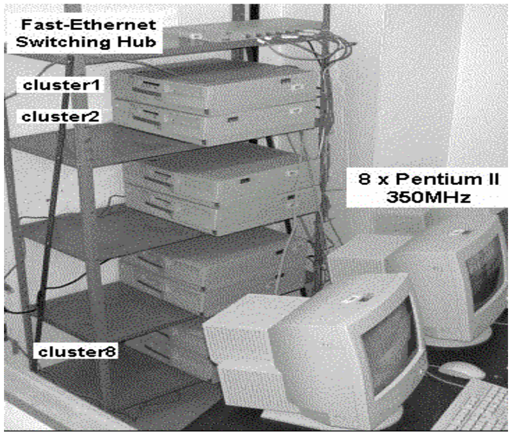
Clusters

Cluster environments are used when applications which require processing performance can not execute in a single node.

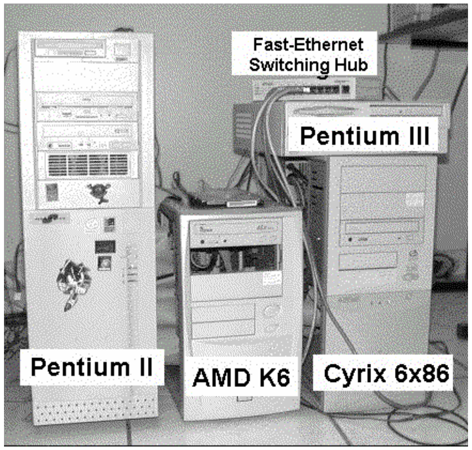
These environments are built with a local connection of many no expensive computers using a specific network equipment.

The following figures present examples of cluster environments.

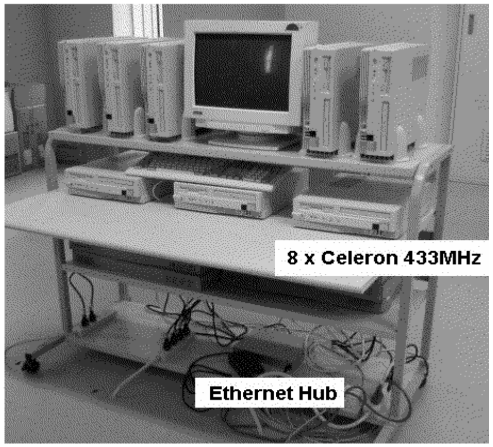
Clusters



Clusters



Clusters

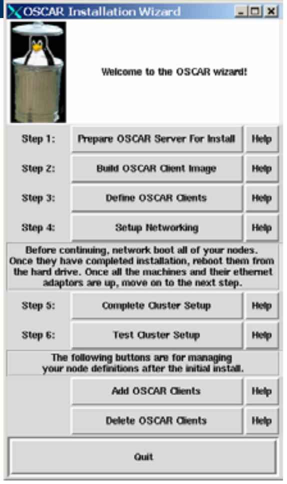


Clusters

Clusters

Clusters

Cluster management is an important task for this new distributed architecture, many packages exist with this specific function (e.g. Oscar)



OSCAR Installation Wizard

Welcome to the OSCAR wizard!

Step 1: Prepare OSCAR Server For Install

Step 2: Build OSCAR Client Image

Step 3: Define OSCAR Clients

Step 4: Setup Networking

Before continuing, network boot all of your nodes. Once they have completed installation, reboot them from the hard drive. Once all the machines and their ethernet adaptors are up, move on to the next step.

Step 5: Complete Cluster Setup

Step 6: Test Cluster Setup

The following buttons are for managing your node definitions after the initial install.

Clusters and Computational Grids

The experimental research with the *I-WAY*, first large scale Grid effort, bring to us that there were five classes of applications using a specific computing paradigm.

Clusters and Computational Grids

Computing paradigms **and** ***applications*** **can be classify as following :**

- **Distributed Supercomputing**
- **High-Throughput Computing**
- **On-Demand Computing**
- **Computing for Large Amount of Data**
- **Collaborative Computing**

Clusters and Computational Grids

1. Distributed Supercomputing

Applications that use this approach can be characterized by the fact that it is not possible to solve these applications in a single computational system.

The aggregation environment which we are referring to can be represented by all the supercomputers of a specific country or all the workstation inside of an organization.

Clusters and Computational Grids

Examples of applications using the *distributed supercomputing* approach are :

- *Distributed Interactive Simulation (DIS)* : this is a simulation technique used to model the behaviour and movement of hundred (or thousand) of entities which are usually employed for military planning and teaching.

Clusters and Computational Grids

- Simulation of complex models such as those in weather forecast and cosmology.

Clusters and Computational Grids

2. High-Throughput Computing

The main objective of this approach it solve the problem of applications that require a transfer of a large amount of data.

The computational environment is used for scheduling a large number of loosely couple tasks and enhance the utilization of machines with a low workload.

Clusters and Computational Grids

Classical examples for *high-throughput computing* are :

- *Condor High-Throughput –* this software environment from the University of Wisconsin is used to manage *pools* of hundreds workstations in the university and other labs around the world.

Clusters and Computational Grids

- The *Platform Computing software* - used by AMD during the projects of K6 e K7 processors. It is reported that the company has used all the desktops which were not in use by the engineers in a specific period of time.

Clusters and Computational Grids

3. On-Demand Computing

This class of applications usually can be characterized by the use of resources that can not be used in the local site, because it is not available.

The ***resources*** can be ***computing***, ***data streams, software, archives*** and for examples ***experimental results.***

Clusters and Computational Grids

Difference between this approach and distributed Supercomputing is related to the cost of performance then the complete performance behaviour.

Clusters and Computational Grids

4. Computing for Large Amount of Data

This class of application and computing paradigm covers the requirement for processing large amount of data stored in a geographic distributed fashion.

Examples are large databases and digital libraries that are available for access in a distributed way.

The Digital Sky Survey and modern weather forecast Systems are applications examples.

Clusters and Computational Grids

5. Collaborative Computing

Examples for this class are those which are oriented to the improvement the relation between humans.

Many collaborative applications allow the share use of computational resources.

Clusters and Computational Grids

NICE is a collaborative learning environment for young children (approximately 6-8 years of age). The environment depicts a virtual island in which the children can tend a virtual garden and learn about environmental concepts.

Users

Another approach used to understand what is a Grid, is to understand who is going to use.

A Grid is above of the mechanisms of resource sharing therefore we can image two questions :

A - Which kind of entity is going to invest in the infrastructure for a Grid ?

B - Which kind of resources each community of the entity will be share ?

Clusters and Computational Grids

Answers for the two questions should be based on costs and benefits for sharing resources.

Therefore it is usually presented in the academic and commercial reports efforts for the following groups of grid environments :

- National
- Private
- Virtual
- Public

Clusters and Computational Grids

- *National Grid* – the target of this group is to be a strategic computational resource and serve as a bridge between national sharing facilities.

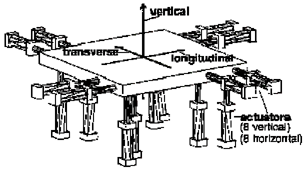
- *Private Grid* – the heath community it is an example of private grid organization. This group, was identified to benefit from grid configurations because of the strategic utilization of computational power.

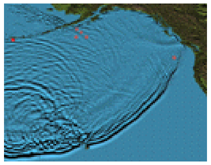
Clusters and Computational Grids

NSF National Technology Grid

Clusters and Computational Grids

- NEESgrid: national infrastructure to couple earthquake engineers with experimental facilities, databases, computers, & each other
- On-demand access to experiments, data streams, computing, archives, collaboration





NEESgrid: Argonne, Michigan, NCSA, UIUC, USC

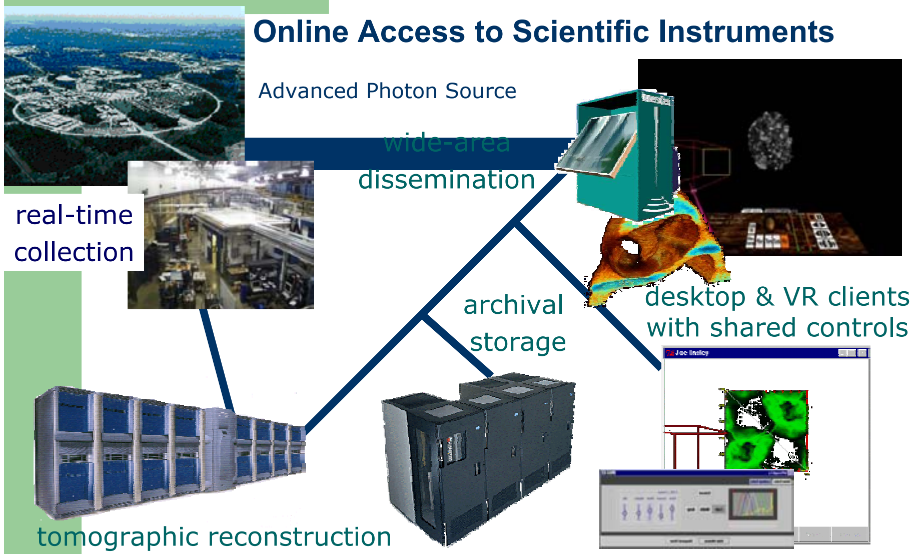
Network for Earthquake Engineering Simulation

Clusters and Computational Grids

- ***Virtual Grid*** **– this community is formed by researches and scientists which require the use of expensive equipments and a great computational power.**

- ***Public Grid*** **– this group is basically characterized by those which the main activity includes services using a great quantity of computational power.**

Online Access to Scientific Instruments



Advanced Photon Source

wide-area dissemination

real-time collection

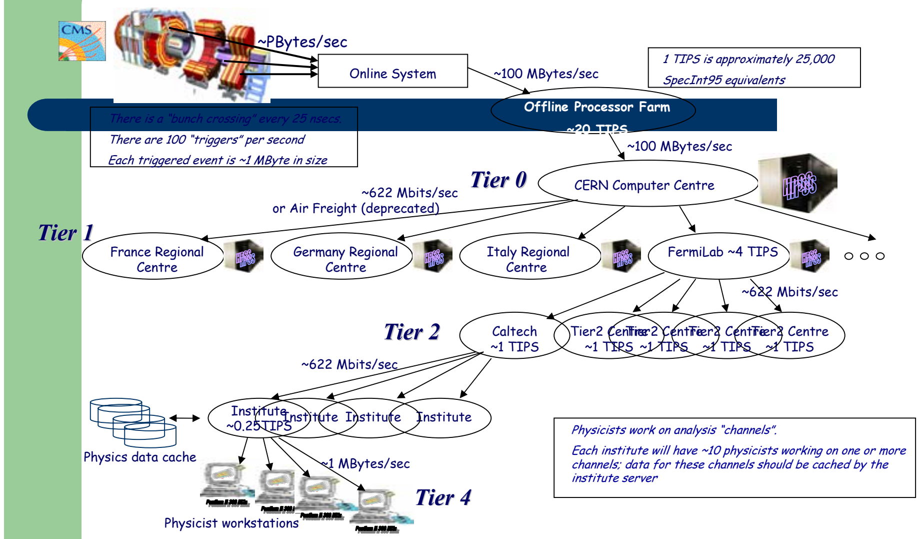
archival storage

desktop & VR clients with shared controls

tomographic reconstruction

DOE X-ray grand challenge: ANL, USC/ISI, NIST, U.Chicago

Data Grids for High Energy Physics



1 TIPS is approximately 25,000 SpecInt95 equivalents

There is a "bunch crossing" every 25 nsecs.
There are 100 "triggers" per second
Each triggered event is ~1 MByte in size

Physicists work on analysis "channels".

Each institute will have ~10 physicists working on one or more channels; data for these channels should be cached by the institute server

Image courtesy Harvey Newman, Caltech

Grid Architecture

Before we start to study the Grid architecture it is interesting to know about ***Virtual Organizations (VO). Virtual organizations*** are the entities that share resources of the Grid under a specific policy .Examples of **VO** are :

- Providers of applications, data storage and computational power.
- Research organizations
- Universities

Clusters and Computational Grids

Virtual Organizations

Virtual Organizations are different from each other considering the following parameters :

- Main objective
- Geographic extension
- Size (or physical dimensions)
- Time to use the facilities
- Structure
- Community

Clusters and Computational Grids

Similar to the experience with *Internet*, researches involved with the Grid established an architecture aiming the interoperability between ***VO***s.

Clusters and Computational Grids

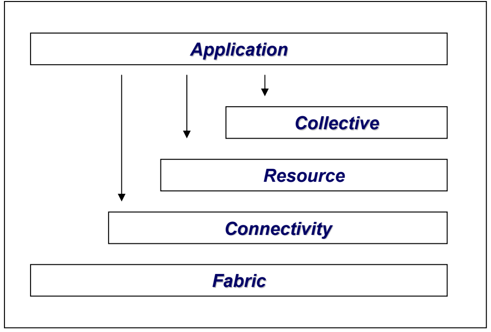
Aspects such as :

- authentication,
- authorization,
- mechanism of message passing,
- resource sharing,
- scheduling and
- load balancing of tasks

are some of issues which a Grid architecture should provide.

Clusters and Computational Grids

A standard Grid architecture was proposed as :

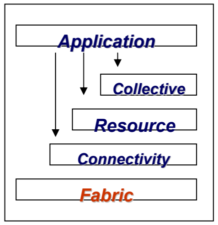


Five Layers Grid Architecture

Clusters and Computational Grids

Fabric –

Components of this layer implement local operations which occurs in each resource mainly because of the sharing provided by the above layers.



Clusters and Computational Grids

Fabric –

Mechanisms are necessary to obtain information about the structure, state and available resources.

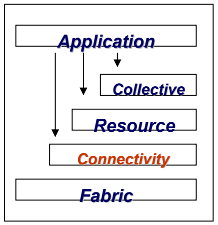
On the other hand, it is also important techniques to management the QoS (Quality of Service) for each query.

Clusters and Computational Grids

Connectivity

In this layer exists the definition of the basic protocols necessary for communication and authentication for a specific transaction of the Grid.

The communication protocols allow the data exchange between the *Fabric layers.* This service includes the transport, routing and name services.



Clusters and Computational Grids

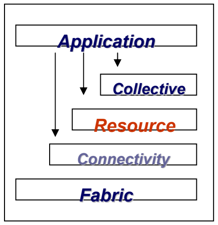
Connectivity

The authentication protocols are responsible for building the communication services which are way to prove secure mechanism to verify the identity of users and resources

Clusters and Computational Grids

Resource

This layer uses the *connectivity* protocols(communication and authentication) to define protocols and APIs to provide security during the negotiation, starting, control, monitoring, creating reports and details involved During the individual resources operations.



Clusters and Computational Grids

Resource

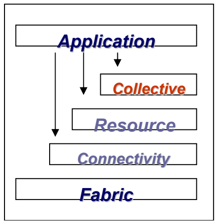
Protocol implementations of this layer utilizes calls from the *Fabric* to access and control local resources.

Clusters and Computational Grids

Collective

The *resource layer* treats the scope of individual resource operations.

On the other hand, in the ***collective layer*** components work with the interaction of resource collections.



Clusters and Computational Grids

Collective

The elements from this layer use the *resource* and *application* layers to implement a variety of services, such as :

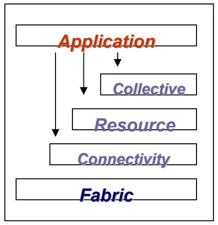
- Directory service : this facility allows members of *virtual organization* to discover which are the resources available

- Common Authorization Servers : this facility is also design to implement a better policy to access resources.

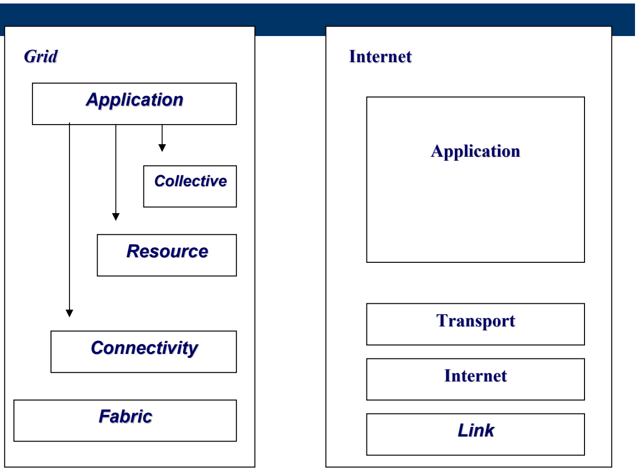
Clusters and Computational Grids

Application

This layer is related to the users´ applications in their *virtual organizations* The previous commented layers provide services for this layer.



Equivalence between the Gird and Internet Models



Grid Computing Environments

Grid Consortiums and Open Forums

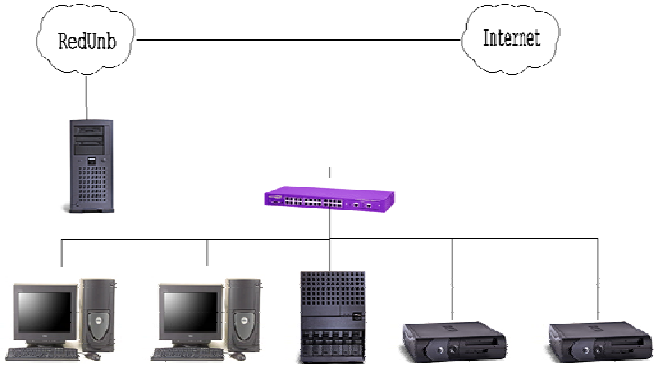
- ***C3CA***
- ***Global Grid Forum***
- ***Australian Grid Forum***
- ***Peer-to-Peer (P2P) Working Group***
- ***eGrid: European Grid Computing Initiative***
- ***Asia Pacific Grid***

Clusters and Computational Grids

Grid Consortiums and Open Forums

- *GridForum Korea*
- *EuroTools SIG on Metacomputing*
- *IEEE Task Force on Cluster Computing*
- *New Productivity Initiative (NPI)*
- *The Distributed Coalition*
- *Content Alliance: About Content Peering*
- *`My´ Brazilian ....*

Clusters and Computational Grids



Clusters and Computational Grids

Grid Middleware

- Cosm P2P Toolkit
- *Globus*
- GRACE: GRid Architecture for Computational Economy
- Gridbus

Clusters and Computational Grids

Grid Middleware

- Grid Datafarm
- GridSim: Toolkit for Grid Resource Modeling and Scheduling Simultation
- Simgrid
- Jxta Peer to Peer Network
- *Legion: A Worldwide Virtual Computer*

Clusters and Computational Grids

DataGrid Initiatives

- Virtual Laboratory: Tools for Data Intensive Science on Grid
- EU DataGrid
- DIDC Data Grid work
- GriPhyN (Grid Physics Network)
- HEPGrid (High Energy Physics and Grid Networks)
- Particle Physics Data Grid (PPDG)
- Datacentric Grid

Clusters and Computational Grids

Grid Systems

- Compute Power Market
- Global Operating Systems
- XtremWeb
- JAVELIN: Java-Based Global Computing
- MILAN: Metacomputing In Large Asynchronous Networks
- Harness Parallel Virtual Machine Project
- Management System for Heterogeneous Networks
- PUNCH - Network Computing Hub
- MOBIDICK

Clusters and Computational Grids

Grid Systems

- Amica
- MultiCluster
- Poland Metacomputing
- Echelon: Agent Based Grid Computing
- Bayanihan
- NeuroGrid
- GridLab
- DAMIEN
- CrossGrid
- DIET

Clusters and Computational Grids

Computational Economy

- GRACE: GRid Architecture for Computational Economy
- Compute Power Market (CPM)
- G-Commerce
- Mariposa: A New Approach to Distributed Data
- The Information Economy
- FORTH Information Economies
- Share Meta
- D'Agent
- Program for Research on the Information Economy

Clusters and Computational Grids

Computational Economy

- Xenoservers - Accountable Execution of Untrusted Programs
- Electricity Trading Over the Internet Begins in Six New England States
- POPCORN
- CSAR: Resource Tokens and Trading Pool
- OCEAN - The Open Computation Exchange & Arbitration Network
- Spawn: A Distributed Computational Economy
- Market-Based Computing

Clusters and Computational Grids

Computational Economy

- W3C effort: Common Markup for micropayment per-fee-links
- Agent-Based Computational Economics
- Electronic Brokerage
- Society for Computational Economics
- Internet Ecologies

Clusters and Computational Grids

Grid Schedulers

- Nimrod/G Grid Resource Broker
- AppLeS
- SILVER Metascheduler
- ST-ORM
- Condor/G
- NetSolve
- DISCWorld
- Computing Centre Software (CCS)

Clusters and Computational Grids

Grid Portals

- ActiveSheets
- UNICORE - Uniform Interface to Computing Resources
- SDSC GridPort Toolkit
- Enginframe
- Lecce GRB Portal
- Grid Enabled Desktop Environments
- Interactive Control and Debugging of Distribution- IC2D
- NLANR Grid Portal Development Kit

Clusters and Computational Grids

Grid Programming Environments

•Nimrod - A tool for distributed parametric modeling
•Ninf
•Cactus Code
•MetaMPI - Flexible Coupling of Heterogeneous MPI Systems
•Virtual Distributed Computing Environment
•GrADS: Grid Application Development Software Project

Clusters and Computational Grids

Grid Programming Environments

•Jave-based CoG Kit
•GAF3J - Grid Application Framework for Java
•ProActive PDC
•REDISE - Remote and Distributed Software Engineering
•Albatross: Wide Area Cluster Computing

Clusters and Computational Grids

Grid Performance Monitoring and Forecasting

- Network Weather Service
- NetLogger
- Remos

Clusters and Computational Grids

Grid Testbeds and Developments

- World Wide Grid (WWG)
- Polder Metacomputer
- NASA Information Power Grid (IPG)
- NPACI: Metasystems
- Asia Pacific Bioinformatics Network
- The Distributed ASCI Supercomputer (DAS)
- G-WAAT
- Micro Grid
- Alliance Grid Technologies
- The Alliance Virtual Machine Room
- EuroGrid

Clusters and Computational Grids

Grid Testbeds and Developments

- Internet Movie Project
- Nordic Grid
- ThaiGrid
- TeraGrid
- Irish Computational Grid (ICG)
- GrangeNet
- LHC Grid
- I-Grid

Clusters and Computational Grids

Grid Applications

- Molecular Modelling for Drug Design
- Neuro Science - Brain Activity Analysis
- Cellular Microphysiology
- HEPGrid: High Energy Physics and the Grid Network
- Access Grid
- Globus Applications
- The International Grid (iGrid)
- UK Grid Apps Working Group
- NLANR Distributed Applications
- DataGRID - WP9: Earth Observation Science Application

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Grid Applications

- Particle Physics Data Grid
- DREAM project: Evolutionary Computing and Agents Applications
- Knowledge Grid
- Fusion Collaboratory
- APEC Cooperation for Earthquake Simulation
- Australian Computational Earth Systems Simulator
- EarthSystemGrid

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Grid Applications

- Australian Virtual Observatory
- US Virtual Observatory
- Distributed Proofreaders
- NEESgrid: Earthquake Engineering Virtual Collaboratory
- Geodise: Aerospace Design Optimisation
- Japanese BioGrid

Experimental Results

Globus

The *Globus* software environment is a project developed by *Argonne National Laboratory* (ANL) and *University of Southern California.* In our work we use the version 1.1.4 of t he Globus software package because this release provides support to MPI applications.

The Globus environment is composed by a set of components implementing basic services to resource allocation, communication, security, process management and access to remote data .

Clusters and Computational Grids

The resource allocation component of the Globus environment (GRAM - *Globus Resource Allocation Manager*) is the element that acts as an interface between global and local services.

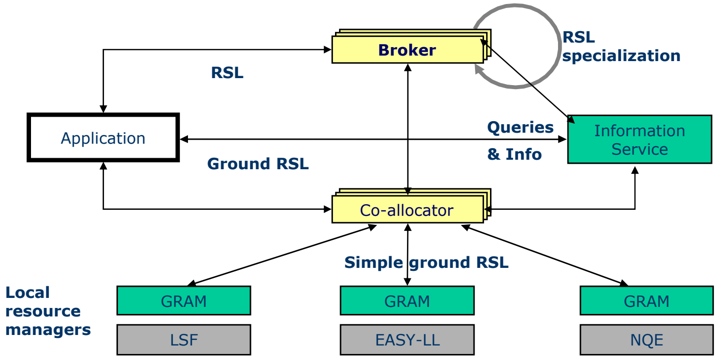
Application programmers use the GRAM element, through the *gatekeeper* software portion which is responsible for the user authentication and association with a local computer account.

Clusters and Computational Grids

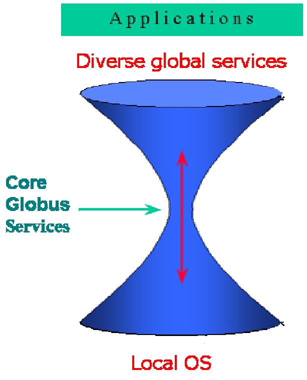
The mechanism to identify users of the *grid* is based on a file called *map-file*. In this file exists information about authorized users of the *grid configuration.*

Any requirement for resource should be translated to the *Resource Specification Language (RSL)*.

Clusters and Computational Grids



Clusters and Computational Grids


Applications

Diverse global services

Core Globus Services

Local OS

Clusters and Computational Grids

Communication in the Globus environment is performed using a communication library called *Nexus*. This component defines low a level API to support high level programming paradigms.

Examples of high level programming paradigms supported are message passing, remote procedure call and remote I/O procedures.

The information about the system and the *grid configuration* are management by a component called *Metacomputing Directory Service (MDS)*.

Clusters and Computational Grids

An important aspect of the Globus software environment is the security.

This software tool employs the certificate approach, which is carried by a CA (Certificate Authority) using the protocol *Secure Socket Layer* (SSL)

Clusters and Computational Grids

Legion

The *Legion* software environment is a system object oriented which is being developed since 1993 at University of Virginia.

This environment has an architecture concept of grid computing providing a unique virtual machine for users´ applications.

The approach of the *Legion* is to have some important concepts of a grid configuration (e.g. scalability, easy to program, fault tolerance and security) transparent to final users.

Clusters and Computational Grids

In the *Legion*, every entity such as processing power, RAM memory and storage capacity is represented as objects. Objects communicate with each other using services calls to a remote mechanism.

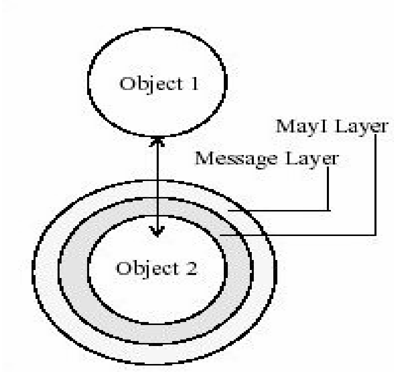
Clusters and Computational Grids

The security component of the *Legion*, as the others elements of this software, is based on an object. The application programmer specifies the security related to an object, where it is defined which type of mechanism is allowed.

In addition, the *Legion* provides some extra basic mechanism to ensure more security.

The *May I* method is an example. Every class should define the method *May I*, which check for a called object the related allowed access.

Clusters and Computational Grids



Clusters and Computational Grids

The traditional system file is emulated in the *Legion* environment through the combination of persistent objects with the global information of object identification.

This approach simplifies the manipulation of files to application programmers. In addition, it is allow to users to add fault tolerance characteristics to applications using rollback and recovery mechanisms

Clusters and Computational Grids

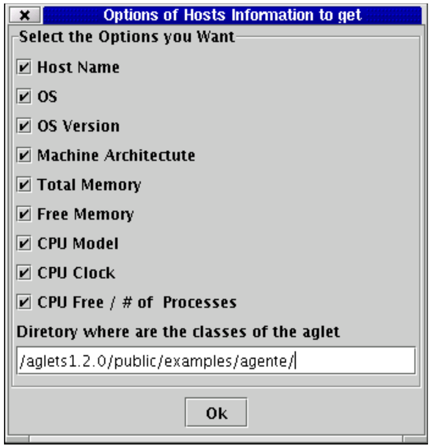
Grid Environment	*Legion*	*Globus*
Software requirement	- OpenSSL 0.9.5 - bin/ksh	- SSLeay 0.9.0 - OpenLDAP 1.2.7
Minimum Disk space	De 250MB a 300 MB	200 MB
Minimum Memory RAM	256 MB	Not specified

Clusters and Computational Grids

A CASE STUDY

Clusters and Computational Grids

Clusters and Computational Grids



Options of Hosts Information to get

Select the Options you Want

☑ Host Name

☑ OS

☑ OS Version

☑ Machine Architectute

☑ Total Memory

☑ Free Memory

☑ CPU Model

☑ CPU Clock

☑ CPU Free / # of Processes

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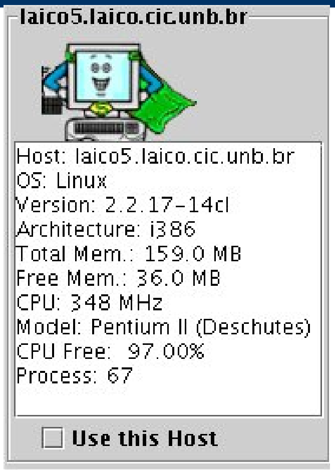
Clusters and Computational Grids



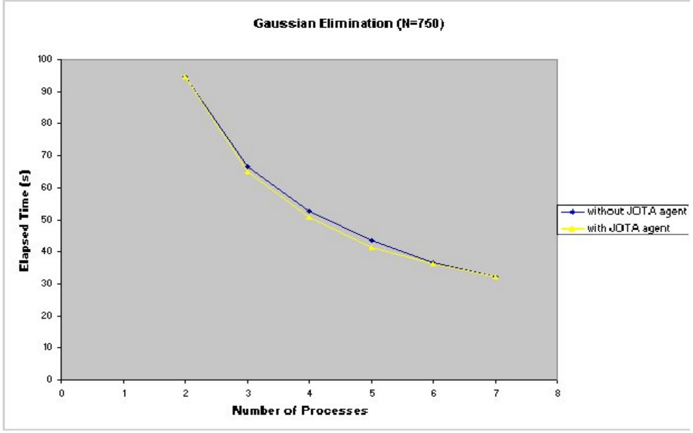
laico5.laico.cic.unb.br

Host: laico5.laico.cic.unb.br
OS: Linux
Version: 2.2.17-14cl
Architecture: i386
Total Mem.: 159.0 MB
Free Mem.: 36.0 MB
CPU: 348 MHz
Model: Pentium II (Deschutes)
CPU Free: 97.00%
Process: 67

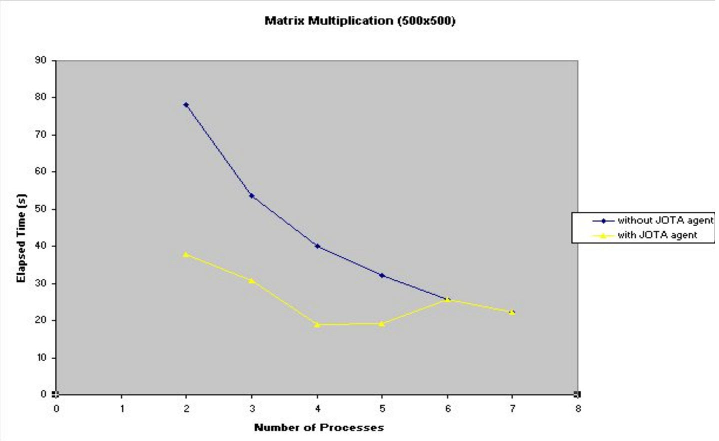
Clusters and Computational Grids

Experimental Results

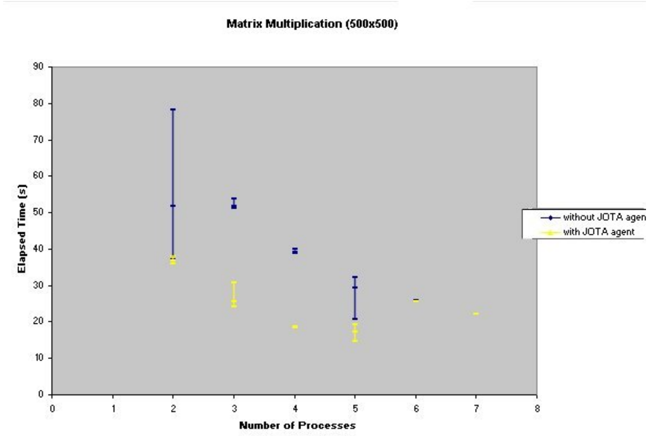
Clusters and Computational Grids



Clusters and Computational Grids



Clusters and Computational Grids



Clusters and Computational Grids

Hardware and Software Environment

Clusters and Computational Grids

After providing some characteristics of the Globus and Legion software tools, in this section we present our grid configuration environment.

It is important to mention that all the machines were in the same laboratory. However, using a *Ethernet Layer 3 Switch* we were able to have the abstraction of a WAN (Wide Area Network) inside this box.

In other words, this equipment could prove the abstraction of a distributed resource environment for our experiments.

Clusters and Computational Grids

Computer Name	**AIX 1**	**AIX 2**	**AIX 3**	**AIX 4**
Operating System	AIX 4.3	AIX 4.3	AIX 4.3	AIX 4.3
Processor	PowerPC_ 604 233 MHz	PowerPC_ 604 233 MHz	PowerPC_ 604 233 MHz	PowerPC_ 604 233 MHz
Memory RAM	256 MB	128 MB	128 MB	512 MB
Hard disk	Two disks of 9 GB	Two disks of 4 GB	Two disks of 4 GB and one 2 GB disk	Two disks of 4 GB and one 2 GB disk
Software Environment	*Legion*	*Globus*	*Globus*	Legion

Table I: The grid environment configuration

Clusters and Computational Grids

The *Legion* software provides a homogeneous view of the *grid* to the application programmer.

The environment uses its own tools to create the homogeneity. The procedure to install the software does not represent any problem, because the application programmer needs only to uncompress binary files and execute some script files. However, for the AIX environment it is necessary more information then those available from the software documents.

Clusters and Computational Grids

We fixed some problems using our background on AIX and exchanging several e-mails with other AIX systems managers. The *Legion* concept of file system represents an advantage of the environment.

The *Legion* file system presents a unique identifier for each object.

Clusters and Computational Grids

This approach provides application programmers the facility to access files widely distributed only using their names.

In other words, the users only use the name of the file, which can be storage in a local or remote machine.

On the other hand, we have verified some problems with the package. As a first problem, we can mention the necessary installation of the entire environment when the *bootstrap host* has a power failure.

Clusters and Computational Grids

The *bootstrap host* is responsible for the domain control. Another drawback of the environment is the low communication rate between objects.

The paradigm of the *Legion* is to be a *framework environment,* where users can develop their own tools, such as security and fault tolerance facilities.

This freedom can represent some flexibility to any developers group. However, it does not allow the use external tools.

Experimental Results

Clusters and Computational Grids

The *Globus* approach allows users to use existing system available tools and have a uniform interface to the gird environment. Interesting features of the *Globus* environment are related to the security and to the autonomy of the configuration.

Experimental Results

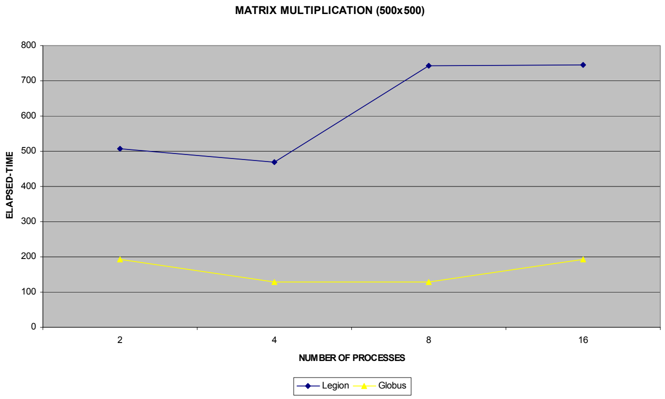
Clusters and Computational Grids

The system has an infrastructure based on X509 certificate and the use the mutual authentification. On the other hand, one drawback of the software is the scalability, which can be understood as the capability to add new resources and new sites.

When considering new facilities application programmers are required to have account into all new hosts.

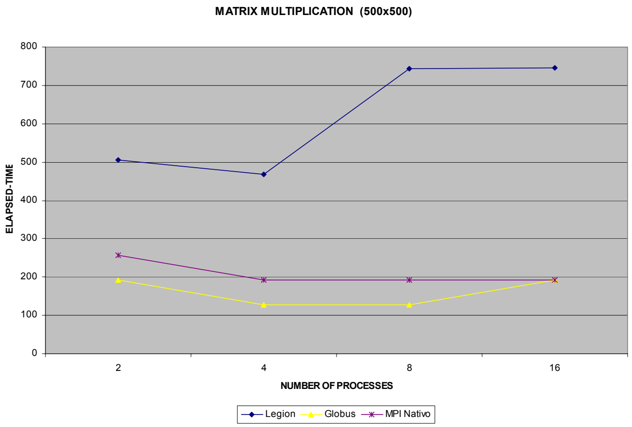
Experimental Results

Clusters and Computational Grids



Experimental Results

Clusters and Computational Grids



End of Part III
(Clusters and Computational Grids)