Server Architectures: Evolution of Software Technologies

January 2005

René J. Chevance

Foreword

- **This presentation is an introduction to a set of presentations about server architectures.**
  They are based on the following book:

  Serveurs Architectures: Multiprocessors, Clusters, Parallel Systems, Web Servers, Storage Solutions
  René J. Chevance
  Digital Press December 2004 ISBN 1-55558-333-4
  http://books.elsevier.com/

  This book has been derived from the following one:

  Serveurs multiprocesseurs, clusters et architectures parallèles
  René J. Chevance
  Eyrolles Avril 2000 ISBN 2-212-09114-1
  http://www.eyrolles.com/

  The English version integrates a lot of updates as well as a new chapter on Storage Solutions.

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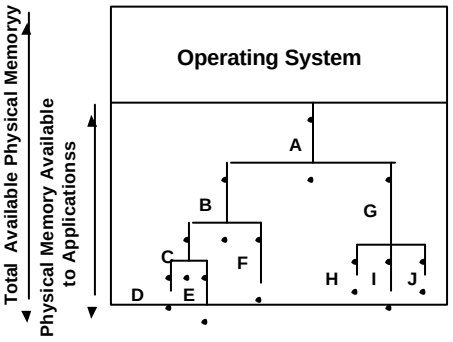
Organization of the Presentations

- Introduction
- Processors and Memories
- Input/Output
- ➔ Evolution of Software Technologies (this presentation)
  - Virtual Memory
  - 64 bit Addressing
  - Operating Systems
  - Client/Server
  - Web Services
  - Transactional Monitors
  - RPC and MOMs
  - Distributed Object Model
  - Enterprise Java Beans
  - Web Servers
  - System Administration
  - Economic model
- Symmetric Multi-Processors
- Cluster and Massively Parallel Machines
- Data Storage
- System Performance and Estimation Techniques
- DBMS and Server Architectures
- High Availability Systems
- Selection Criteria and Total Cost of Possession
- Conclusion and Prospects

Virtual Memory

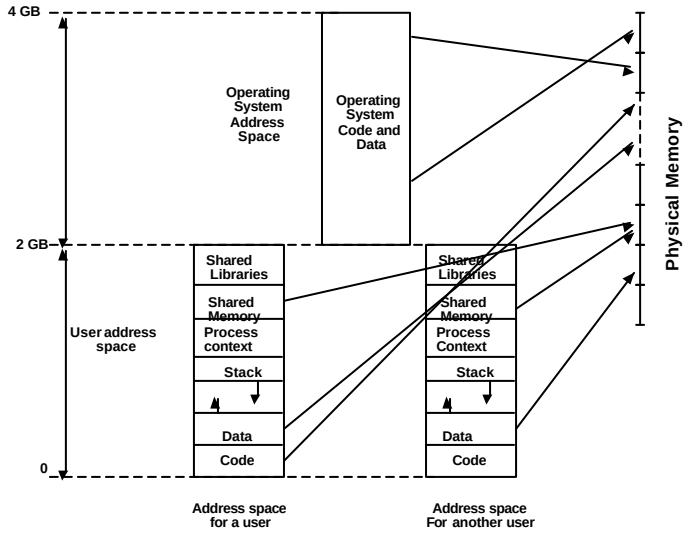
- Without the concept of virtual memory, the mechanism of overlays was used to support objects larger than the amount of physically available memory



- Virtual Memory
  - Virtual memory is (usually) realized onto physical memory on the basis of pages (e.g. 8 KB)
  - Whenever a virtual page has no realization in physical memory, page movement form disk (backing store) is automatically handled by the Operating System (page fault and demand paging mechanism)

Virtual Memory(2)

- **Illustration of the concept of virtual memory (Unix, Windows)**



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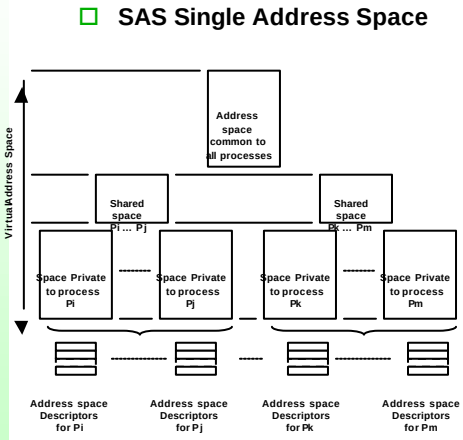
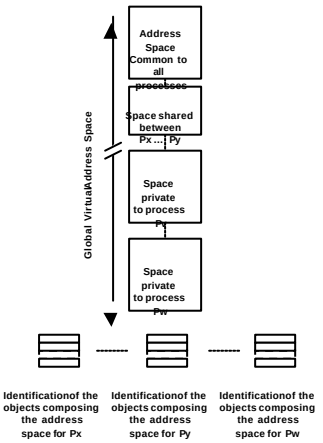
Virtual Memory(3)

- **Two models:**
  - **MAS Multiple Address Spaces (processes re-use the same address space)**
  - **SAS Single Address Space**



a) – MAS Multiple Address Space



b) – SAS Single Address Space

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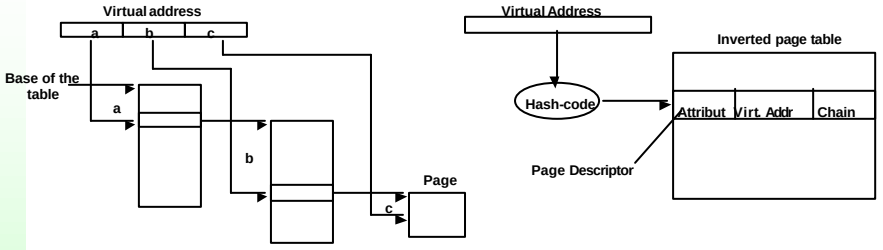
Virtual Memory(4)

- **Virtual Address Translation Mechanisms**



1) - Classical page table approach

2) - Inverted page table approach

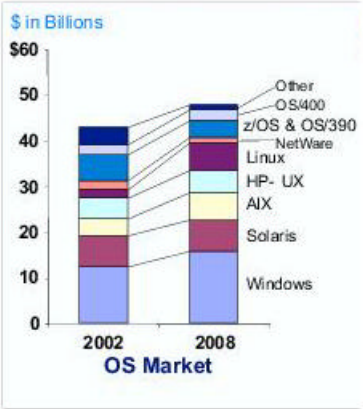
- **Address translation is performed by the processor using address translation caches (TLB – Translation Lookaside Buffers)**
- **Management of the TLB can be done in hardware (performance) or (more frequently now) by software (flexibility)**

64 bit Addressing

- **Supported by most of the processors (RISC, IA-64, AMD and Intel extensions to x86, IBM z Series)**
- **Supported by Operating Systems: Unix, Windows, z/OS**
- Advantages of 64 bit architecture
  - **Support of very large objects (files, databases) directly in virtual memory ➔ Performances**
    - **Address translation done by the processor**
    - **Data migration done by the Operating System (demand paging)**
    - **No need for the software to perform address multiplexing (like buffer management)**
  - **Support of very large file systems (>2 GB)**
  - **Management of very large physical memories**
  - **Becoming a typical requirement of DBMSes and CAD (Computer Aided Design)**

Operating Systems

- **Server sales forecast by operating system (Source Gartner 2003)**



Comments :

- **Proprietary systems market share is decreasing sharply (with the exception of OS/400 and z/OS)**
- **Linux market share is expected to grow quickly**
- **Windows market share is expanding (specially for low and mid-range servers)**
- **The cost of developing and maintaining a proprietary version of Unix is approaching the cost of proprietary systems. This phenomenon is leading to a reduction in the number of Unix versions (to the benefit of Linux)**

Operating Systems(2)

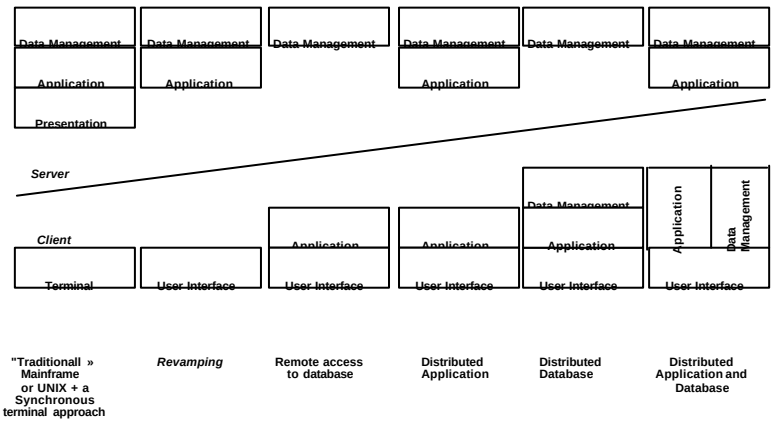
- **Operating Systems Functionality**
  - **Scalability (ideally both dimensions)**
    - **SMP**
    - **Clustering**
  - **RAS: Reliability, Availability and Serviceability**
    - **Masking hardware failures**
    - **Reconfiguration capability**
    - **On-line hardware and software updates**
    - **Checkpoint and restart capability**
    - **System partitioning and clustering**
  - **File System**
    - **Journaling File System**
    - **Logical Volume Management and support of very large files**
    - **Save and restore**
  - **Distributed services and Internet support**
    - **TCP/IP v6**
    - **Support of Internet tools: Browsers, Web Servers, e-Commerce,….**
    - **Directory Services**
    - **Security**
    - **Distributed File Services**
    - **Distributed Time Service**
    - **Inter-Program Communication: RPC (Remote Procedure Call), RMI (Remote Method invocation) or MOM (Message Oriented Middleware)**

Operating Systems(3)

- **Operating Systems Functionality(2)**
  - **System Management**
    - **Hardware configuration management**
    - **Software configuration management**
    - **User management**
    - **Resource management**
    - **Remote management**
    - **Performance analysis**
    - **Batch processing optimizations**
  - **Capacity to simultaneously support various isolated workloads**
    - **Resource allocation must obey stated rules**
    - **Failure independence**
  - **PC Support**

Client/Server

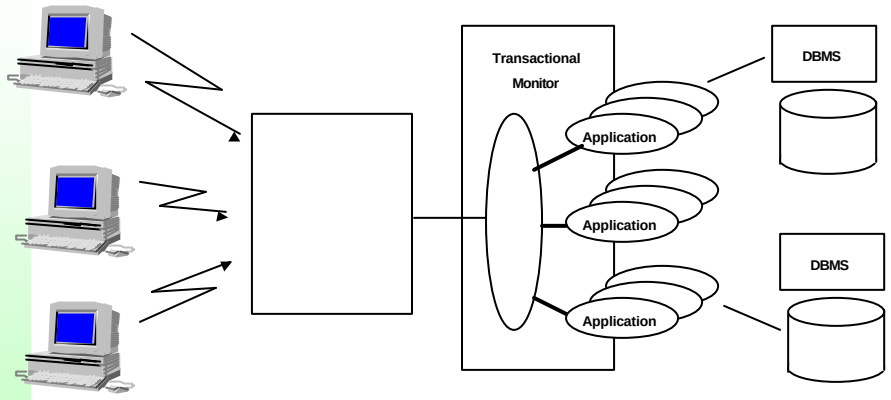
- **Client-Server Architecture options (after Gartner)**



Note: In a Java environment, applications running on the clients are called applets, while those running on the server are known as servlets

Client/Server(2)

- **Multi-Tier Client/Server**



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Components of client-server middleware

- **Middleware components [MEI99]**

	Internet	Dialogue	Data Access	Transactions	Objects	
Application Services	HTTP S-HTP SSL	HTML, Windows, Applets Java	SAG/CLI, RDA, DRDA, ODBC, JDBC	X/Open (Tuxedo, Encina, CICS 6000,...)	ORB (CORBA, COM+, ...)	● ● ●
Distributed Environment Services	System Administration (SNMP, ..)	Directories (LDAP)	Security (Kerberos)	Distributed Time	PVM MPI	● ● ●
Network OS Services	RPC	MOM Message Queues	IPC Remote Inter-Process Communication	Distributed File Systems (NFS, DFS)		● ● ●
Communication Services	TCP/IP					
Operating System Services	Processes And Threads	IPC Local Inter-Process Communication		Local File Systems		● ● ●

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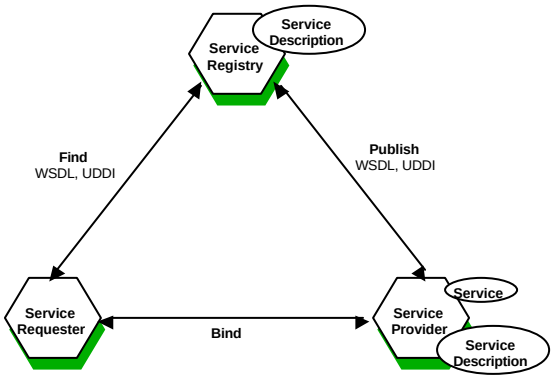
Web Services

- **Web Services Actors, Roles and Operations**
  (Source IBM)



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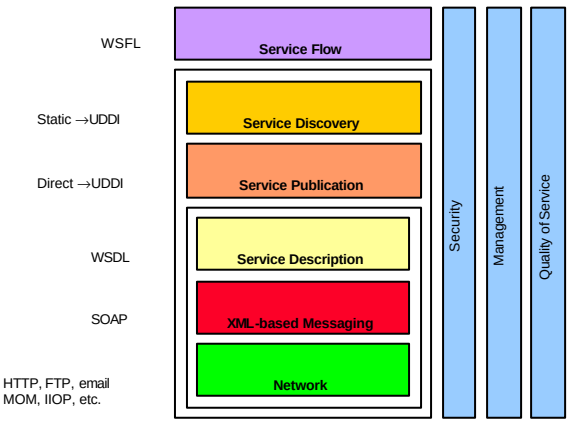
Web Services(2)

- **Web Services Conceptual Stack (Source IBM)**



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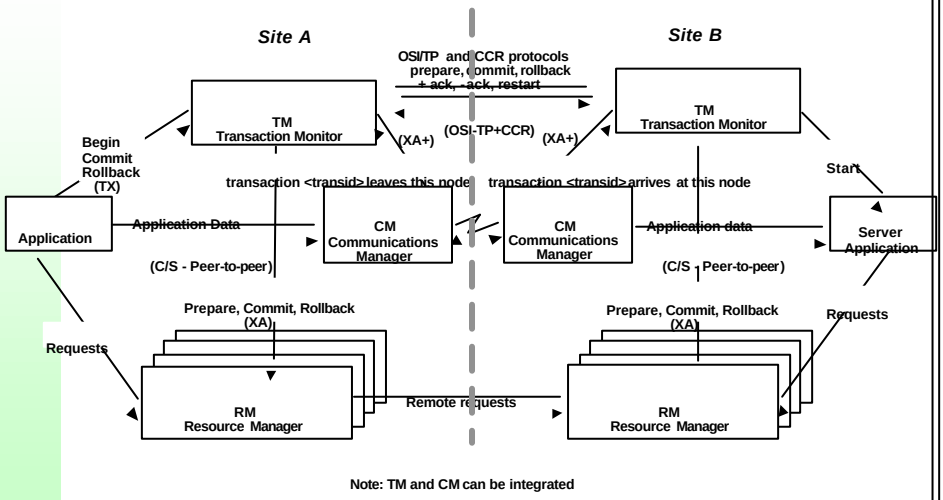
Transactional Monitors

- As very few Operating Systems integrate « native » transactional services, they resort to « transaction monitors » e.g. CICS, Tuxedo
- The support of very large numbers of simultaneous users causes performance problems. The concept of thread was created (in the 60's) to solve this issue (see SMP presentation)
- Functions of a transaction monitor:
  - Thread management, including launching the applications needed to handle user requests (whether users on workstations or requests coming from other systems), controlling their execution and doing load-balancing
  - Transaction management (ensuring that the ACID properties are respected) in a context which may be distributed and which can have several database managers involved in transaction execution.

Transactional Monitors(2)

- X/Open DTP Model [GRA93]



Note: TM and CM can be integrated

Transactional Monitors(3)

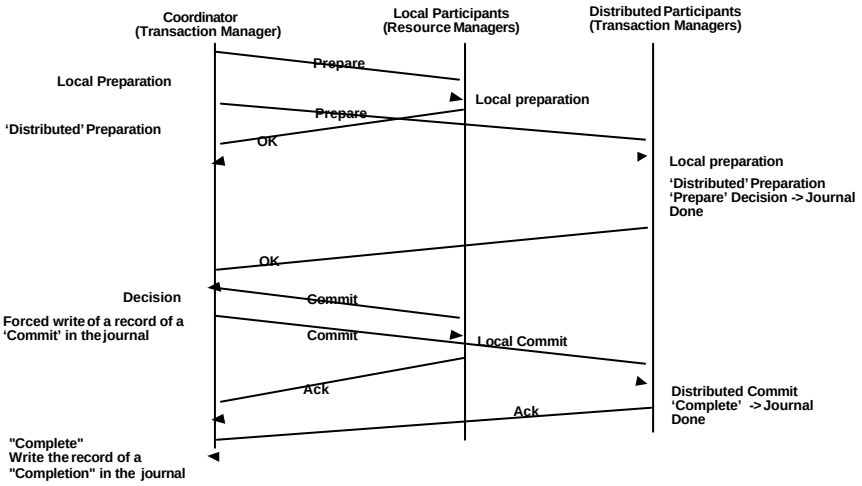
- **X/Open DTP Model(2)**

Participating elements	Protocol or interface (API)	Organization Involved
Application-TM	TX	X/Open DTP
Application-RM	Specific to RM	RM suppliers
Application- serveur	client-server type communications	OSI and application suppliers
TM-RM	XA	X/Open DTP
TM-CM	XA+	X/Open DTP
TM-TM	OSI-TP + CCR	OSI

- **Three possibilities for Client/Server communication:**
  - **A 'transactional' RPC (Remote Procedure Call) or RMI (Remote Method Invocation), so-called because the RPC or RMI mechanism (which here is just a CM) must use the XA+ interface to communicate with TM**
  - **A Peer to Peer dialog**
  - **A Message-Oriented Middleware, or MOM**

Transactional Monitors(4)

- **Principles of the Two-Phase Commit Protocol**

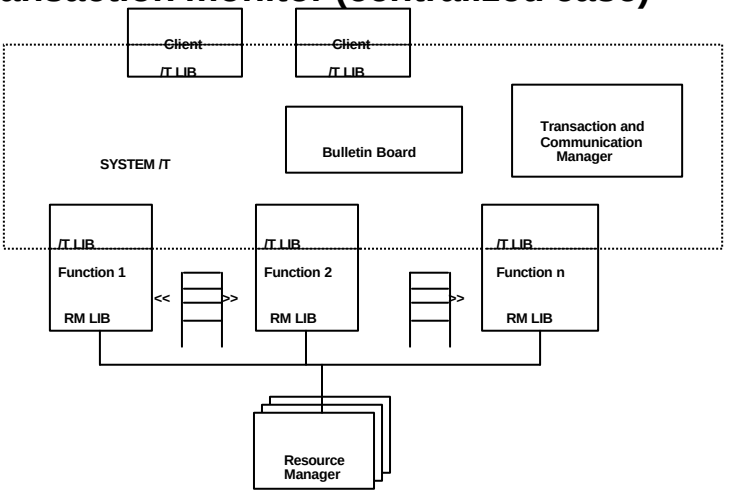


Transactional Monitors(5)

- **Example of a transactional monitor: Tuxedo**
  - Initially developed by AT&T for Unix to fufil its own, owned know by BEA (after USL - Unix System Laboratories and Novell)
  - Commercially available in 1989. Several thousands systems installed
  - Available on a wide variety of systems
  - Characteristics
    - Conform to the X/Open DTP Model (Distributed Transaction Processing)
    - Portability
    - High Level Language support (e.g. Visual Basic, Cobol)
    - Client/Serveur architecture
    - System management
    - Clients - Servers multiplexing (threading)
    - Queueing mechanism
    - Distributed transactions
    - Security

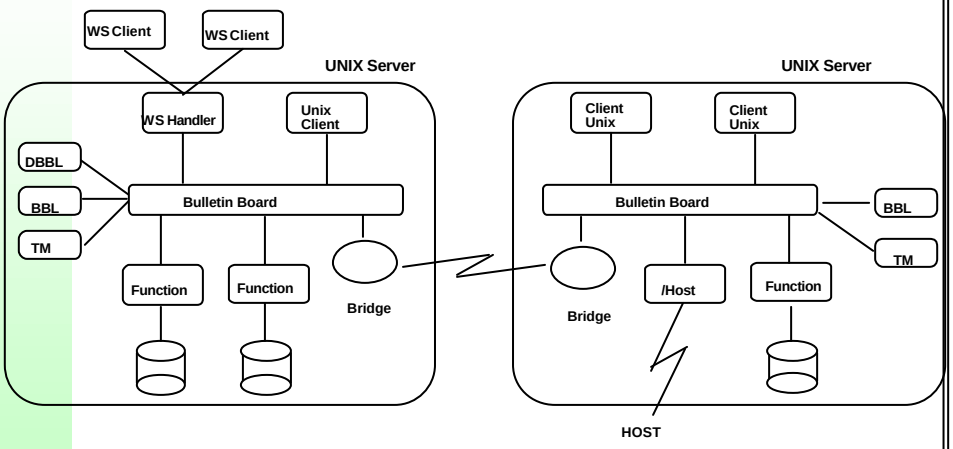
Transactional Monitors(6)

- **Tuxedo, an example of architecture of a transaction monitor (centralized case)**



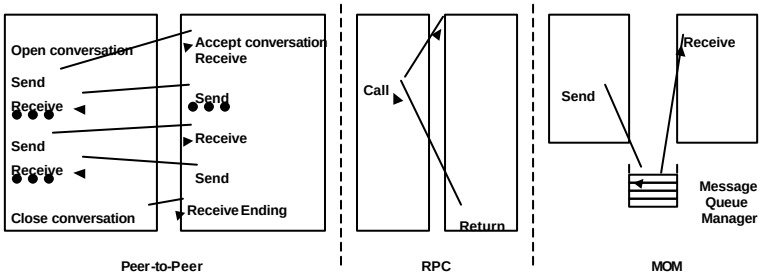
Transactional Monitors(7)

- **Tuxedo, an example of architecture of a transaction monitor (distributed case)**



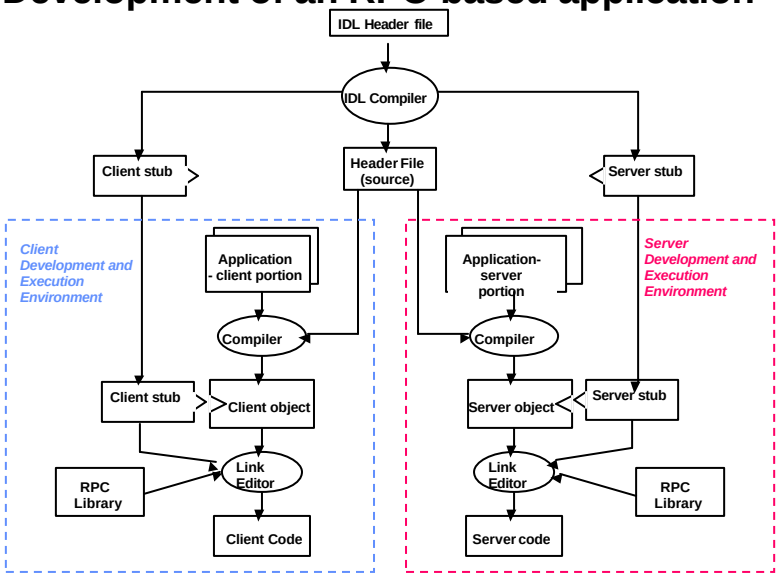
RPC and MOMs

- **Modes of communication between programs:**
  - **Peer-to-peer**
  - **RPC (Remote Procedure Call) or RMI (Remote Methode Invocation)**
  - **MOM (Message Oriented Middleware)**



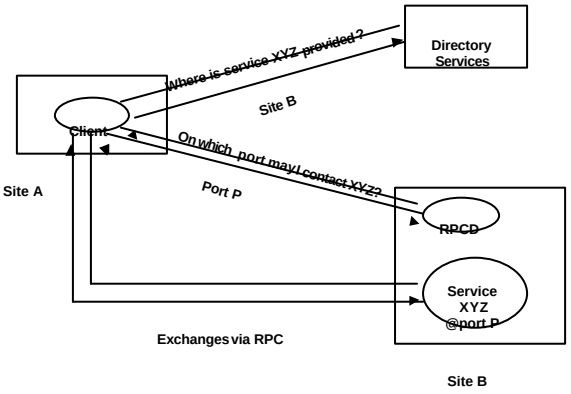
RPC and MOMs(2)

- **Development of an RPC-based application**



RPC and MOMs(3)

- **Operation of an RPC**



RPC and MOMs(4)

- **Comparing the Characteristics of RPC and MOM**

Characteristic	MOM	RPC
Metaphor	Mail	Telephones (without answering machine)
Temporal relation between client and server	Asynchronous	Synchronous
Nature of the communications	Queue	Request-answer
Operational state of the server	Not necessary	Mandatory
Load Balancing	Policy of extraction of the messages (priority system)	By means of a transaction monitor
Transaction support	Depends on the product	Depends on the product (required of a transactional RPC)
Message filtering	Possible	No
Performance	Slow if messages are made secure by writing to disk	More effective than MOM since call parameters are not saved to disk

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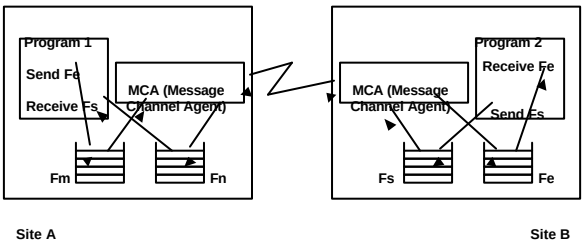
RPC and MOMs(5)

- **Communication by means of MQSeries**



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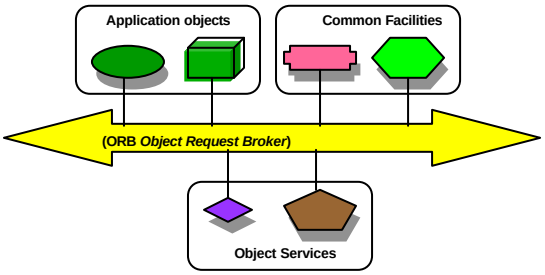
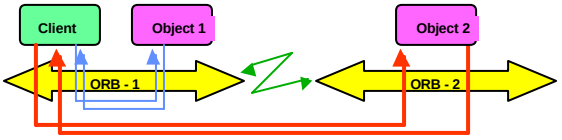
Distributed Object Model

- **CORBA Reference Model**



- **Exchanges with the ORB**



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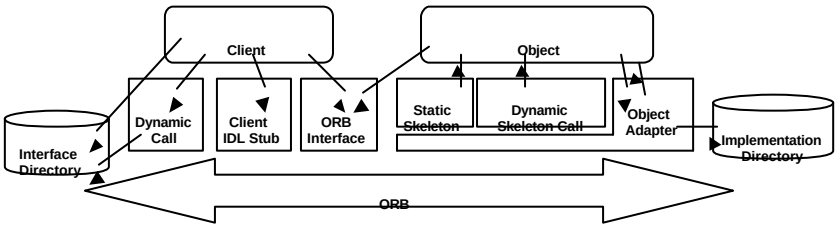
Distributed Object Model(2)

- **Functional architecture of CORBA**



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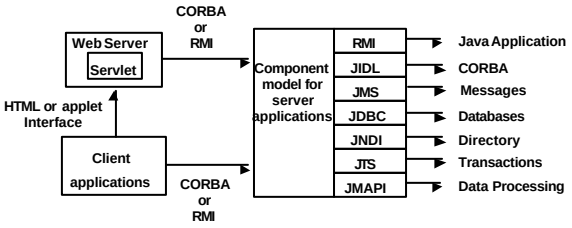
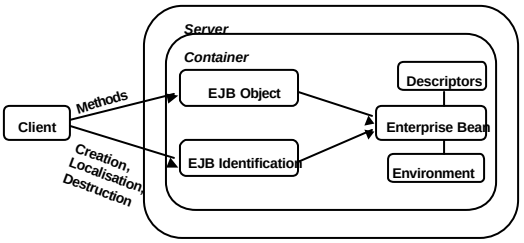
Enterprise Java Beans

- **Enterprise Java Beans – A Component-Oriented Application Model**
  - **EJB Support Services**

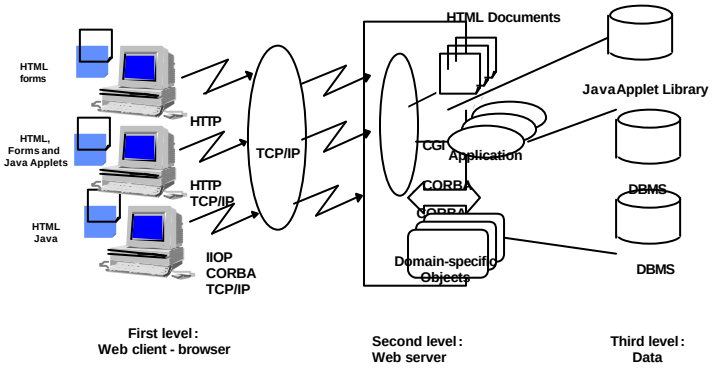


  - **Structure of an EJB Container**



Web Servers

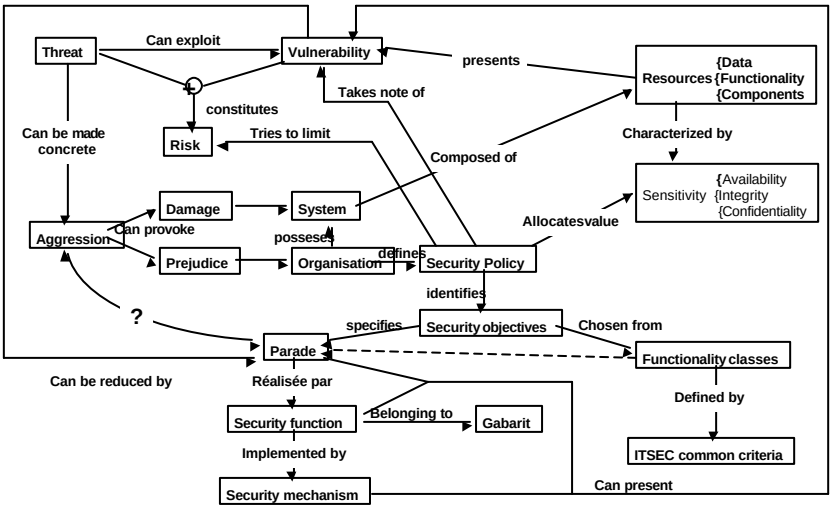
- **Examples of basic technologies used in Web Servers**



Also widely used: Script languages, Mobile code (Java), XML for data exchange, agents,....

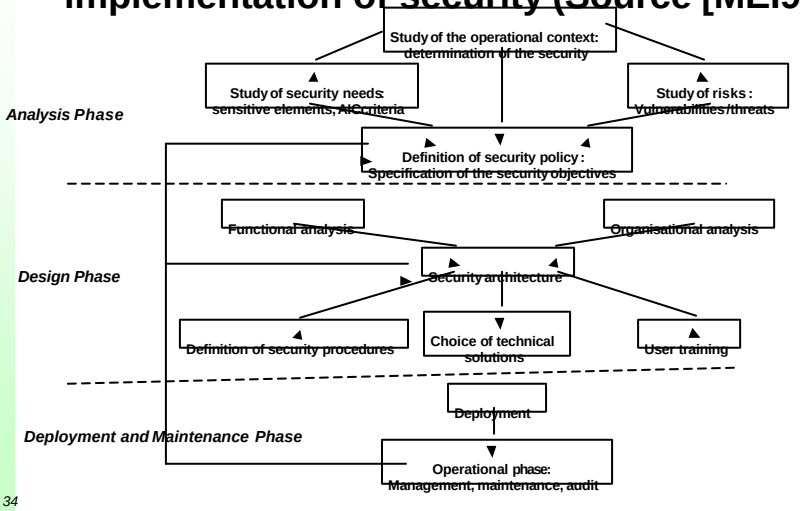
Security

- **Security Concepts (Source [MEI98])**



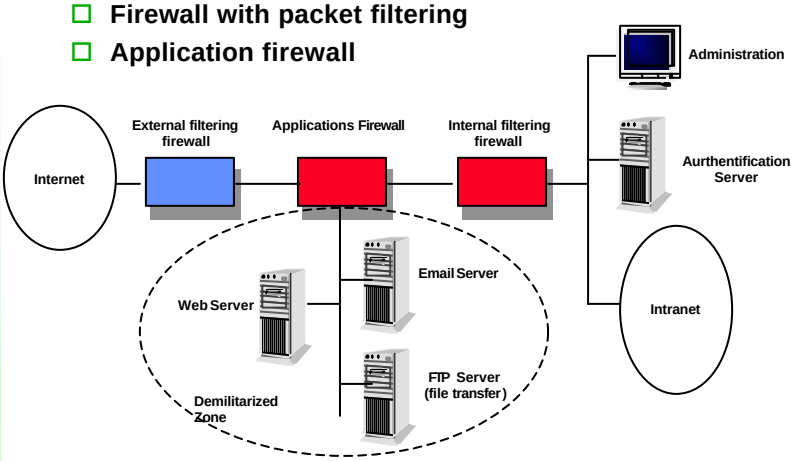
Security(2)

- **Methodological step by step implementation of security (Source [MEI98])**



Security(3)

- **Example of a system using the 2 firewalls techniques:**
  - **Firewall with packet filtering**
  - **Application firewall**



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System Administration

- **System administration covers:**
  - **Management of users and their rights with respect to resources and applications**
  - **Management of equipment, work groups and their rights**
  - **Administration of databases**
  - **Management of the equipment base and associated resources, software in particular, from the point of purchase to their destruction or sale**
  - **Incident management**
  - **Monitoring, optimization and automation of system usage, in particular for batch processing**
  - **Monitoring, optimization and automation of the use of networks**
  - **Management workstation (i.e, a single workstation to manage all systems, local and remote), definition of usage scenarios and reconfiguration (in general through the use of scripts)**
  - **Automatic management of backups and restores**
  - **Measurement of quality of service (QoS, publishing reports on QoS, improvement of QoS, etc.**

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Economic Model

- **Scale Effects :**
  - **Hardware: continuous price decrease due to to volume production (e.g. for microprocessors, below several millions of units, design cost redominates)**
  - **Software:**
    - **Manufacturing cost is almost « zero » (distribution via Internet, online documentation)**
    - **Design and development cost dominates:**
      - **e.g. for a $10M software component:**
        - **for a vendor of moderate volumes: never develop any software which is expected to sell less than 100,000 copies; given a price/development cost ratio of 10:1, this means the software must be sold for $1000.**
        - **for a high-volume vendor: never develop any software which is expected to sell less than 1,000,000 copies ; given a price/development cost ratio of 10:1, this means the software must be sold for $100**

Economic Model(2)

- **Number of lines of code in various operating systems (Source: [MOO99])**

Operating system	Estimate of the number of lines of code (million of lines)
Windows 3.11	3
Windows 95	14
Windows 98	18
Windows NT 4.0	16.5
Windows 2000	35
OS/2	2
Netware 5.0	10
UNIX (average)	12
Linux	5 to 6 (still growing)
OS/400 (v4.r3)	40
MVS (OS 390 and extensions)	9-18

- **Comments:**
  - **For some of these systems, the estimate integrates DBMS or user interface**
  - **Cost of man/year (US 2002): about $150K**
  - **Programmer's productivity: 2000 lines of code/year**
  - **So, $10M → 133,000 (new) lines of code**

References

[GRA93] **Jim Gray, Andreas Reuter « Transaction Processing: Concepts and, Techniques »**
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