CS4513 Distributed Computer Systems

Introduction

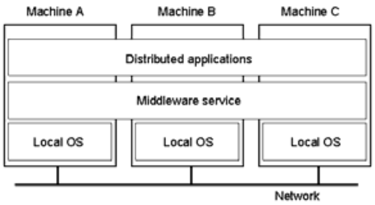
Outline

- Overview
- Goals
- Software
- Client Server

The Rise of Distributed Systems

- Computer hardware prices falling, power increasing
  - If cars the same, Rolls Royce would cost 1 dollar and get 1 billion miles per gallon (with 200 page manual to open the door)
- Network connectivity increasing
  - Everyone is connected with fat pipes
- It is *easy* to connect hardware together
- Definition: a *distributed system* is
  - A collection of independent computers that appears to its users as a single coherent system.

Definition of a Distributed System



Examples:
-The Web
-Processor Pool
-Airline Reservation

A distributed system organized as middleware. Note that the middleware layer extends over multiple machines.

Users can interact with the system in a consistent way, regardless of where the interaction takes place.

Note: Middleware may be "part" of application in practice.

Transparency in a Distributed System

Transparency	Description
Access	Hide differences in data representation and how a resource is accessed
Location	Hide where a resource is located
Migration	Hide that a resource may move to another location
Relocation	Hide that a resource may be moved to another location while in use
Replication	Hide that a resource may be shared by several competitive users
Concurrency	Hide that a resource may be shared by several competitive users
Failure	Hide the failure and recovery of a resource
Persistence	Hide whether a (software) resource is in memory or on disk

Different forms of transparency in a distributed system.

Scalability Problems

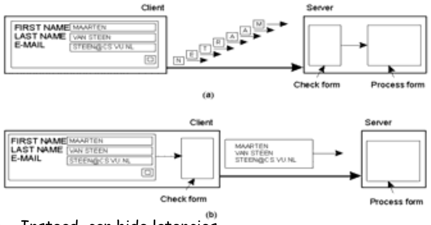
- As distributed systems grow, centralized solutions are limited
  - Consider LAN name resolution vs. WAN

Concept	Example
Centralized services	A single server for all users
Centralized data	A single on-line telephone book
Centralized algorithms	Doing routing based on complete information

- Sometimes, hard to avoid (consider a bank)
- Need to collect information in distributed fashion and distributed in a distributed fashion
- Challenges:
  - geography, ownership domains, time synchronization

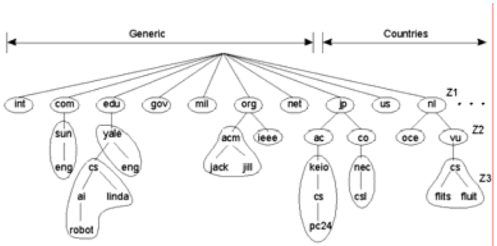
Scaling Techniques: Hiding Communication Latency

- Especially important for interactive applications
- If possible, do *asynchronous communication*
  - Not always possible when client has nothing to do



- Instead, can hide latencies

Scaling Techniques: Distribution



Example: DNS name space into zones
(`nl.vu.cs.fluit` – `z1` gives address of `vu` gives address of `cs`)

Scaling Techniques: Replication

- Copy of information to increase availability and decrease centralized load
  - Example: P2P networks (Gnutella +) distribute copies uniformly or in proportion to use
  - Example: CDNs (akamai)
  - Example: Caching is a replication decision made by client
- Issue: Consistency of replicated information
  - Example: Web Browser cache

Outline

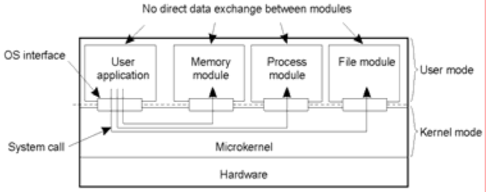
- Overview (done)
- Goals (done)
- Software ←
- Client Server

Software Concepts

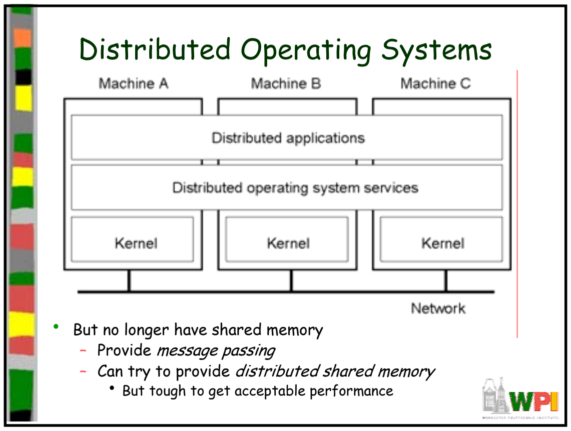
System	Description	Main Goal
DOS	Tightly-coupled operating system for multi-processors and homogeneous multicomputers	Hide and manage hardware resources
NOS	Loosely-coupled operating system for heterogeneous multicomputers (LAN and WAN)	Offer local services to remote clients
Middleware	Additional layer atop of NOS implementing general-purpose services	Provide distribution transparency

- DOS (Distributed Operating Systems)
- NOS (Network Operating Systems)
- Middleware

Uniprocessor Operating Systems



- Separating applications from operating system code through a microkernel
  - Can extend to multiple computers



Distributed Operating Systems

Machine A Machine B Machine C

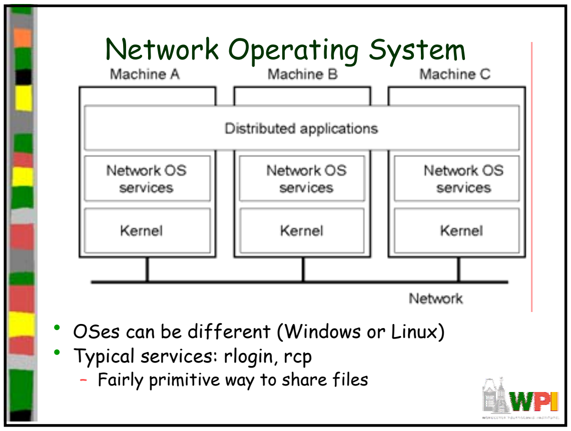
Distributed applications

Distributed operating system services

Kernel Kernel Kernel

Network

- But no longer have shared memory
  - Provide *message passing*
  - Can try to provide *distributed shared memory*
    - But tough to get acceptable performance



Network Operating System

Machine A Machine B Machine C

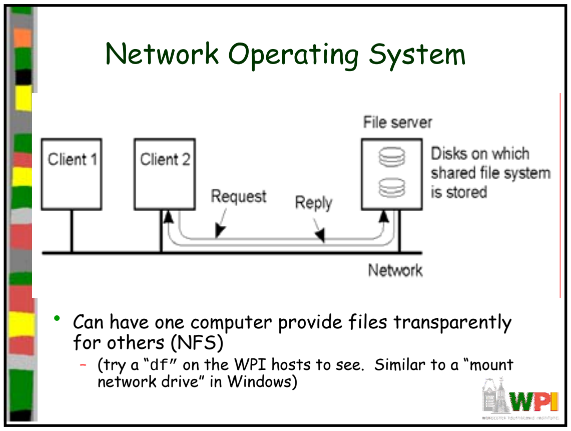
Distributed applications

Network OS services Network OS services Network OS services

Kernel Kernel Kernel

Network

- OSes can be different (Windows or Linux)
- Typical services: rlogin, rcp
  - Fairly primitive way to share files



Network Operating System

File server

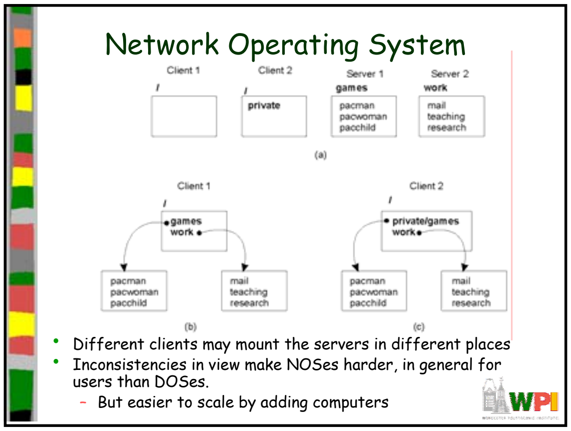
Client 1 Client 2

Disks on which shared file system is stored

Request Reply

Network

- Can have one computer provide files transparently for others (NFS)
  - (try a "df" on the WPI hosts to see. Similar to a "mount network drive" in Windows)



Network Operating System

Client 1 Client 2 Server 1 Server 2

/ / private games pacman pacwoman pacchild work mail teaching research

(a)

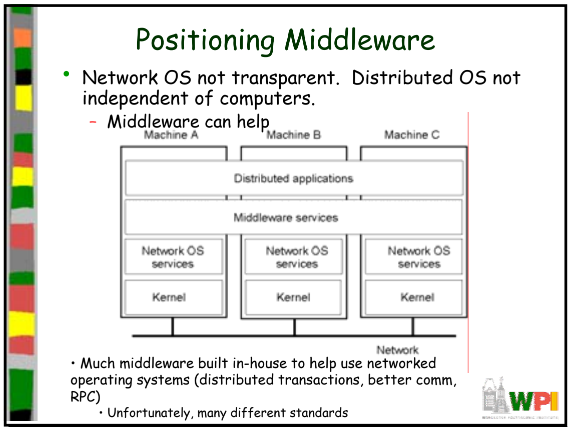
Client 1 / games work pacman pacwoman pacchild mail teaching research

(b)

Client 2 / private/games work pacman pacwoman pacchild mail teaching research

(c)

- Different clients may mount the servers in different places
- Inconsistencies in view make NOSes harder, in general for users than DOSes.
  - But easier to scale by adding computers



Positioning Middleware

- Network OS not transparent. Distributed OS not independent of computers.
  - Middleware can help

Machine A Machine B Machine C

Distributed applications

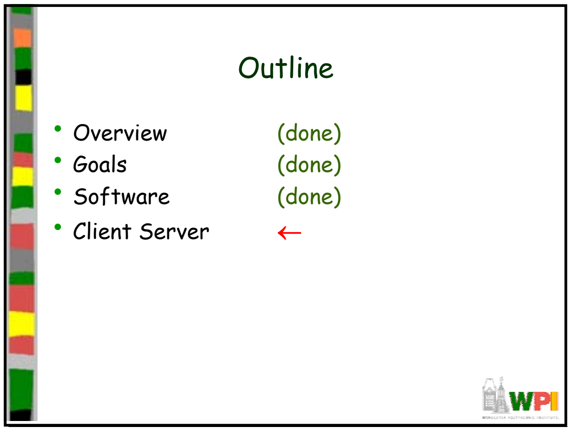
Middleware services

Network OS services Network OS services Network OS services

Kernel Kernel Kernel

Network

- Much middleware built in-house to help use networked operating systems (distributed transactions, better comm, RPC)
  - Unfortunately, many different standards



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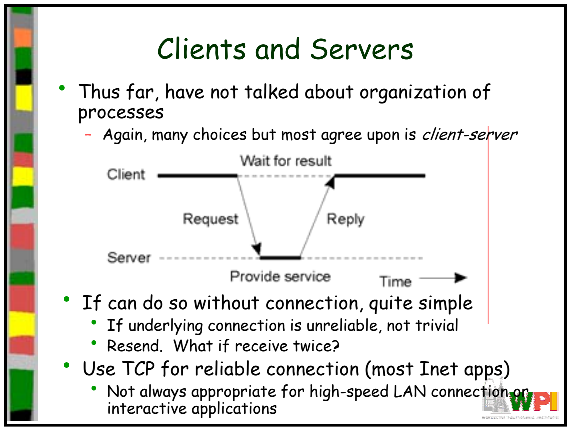
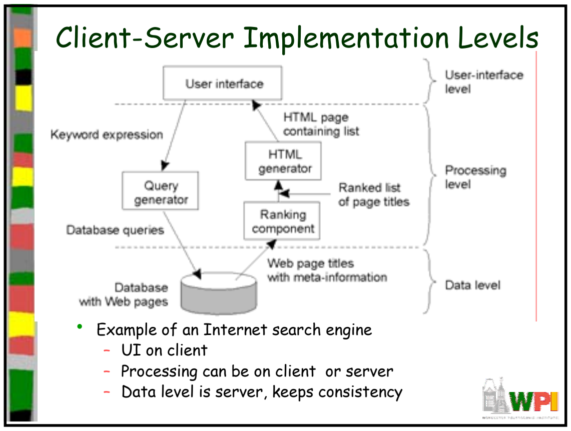


Clients and Servers

- Thus far, have not talked about organization of processes
  - Again, many choices but most agree upon is *client-server*

Wait for result
Client
Request
Reply
Server
Provide service
Time

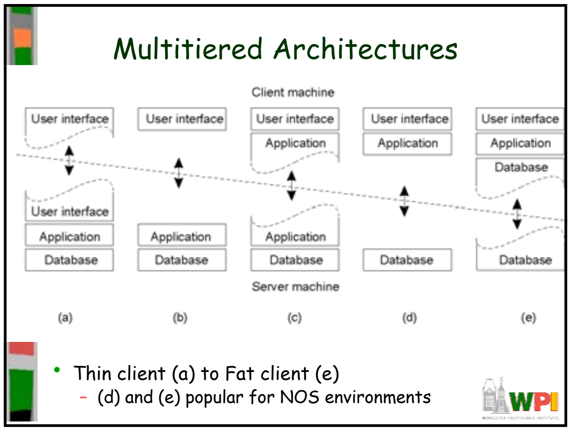
- If can do so without connection, quite simple
  - If underlying connection is unreliable, not trivial
  - Resend. What if receive twice?
- Use TCP for reliable connection (most Inet apps)
  - Not always appropriate for high-speed LAN connection or interactive applications



Client-Server Implementation Levels

User interface
User-interface level
HTML page containing list
Keyword expression
HTML generator
Processing level
Query generator
Ranked list of page titles
Ranking component
Database queries
Web page titles with meta-information
Database with Web pages
Data level

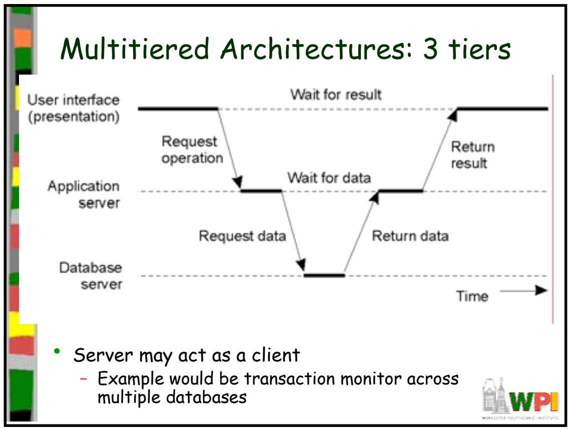
- Example of an Internet search engine
  - UI on client
  - Processing can be on client or server
  - Data level is server, keeps consistency



Multitiered Architectures

Client machine
User interface
User interface
User interface
Application
User interface
Application
User interface
Application
Database
User interface
Application
Database
Application
Database
Application
Database
Database
Database
Server machine
(a)
(b)
(c)
(d)
(e)

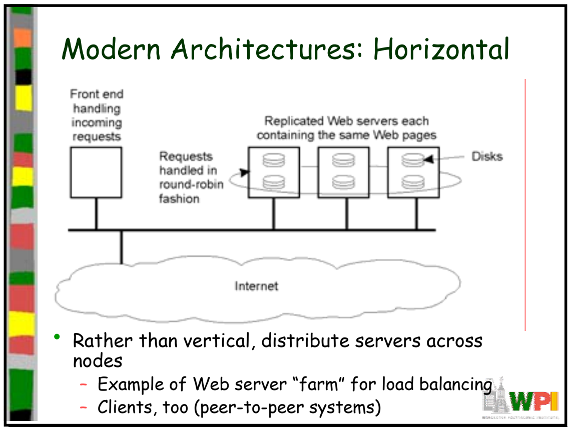
- Thin client (a) to Fat client (e)
  - (d) and (e) popular for NOS environments



Multitiered Architectures: 3 tiers

User interface (presentation)
Wait for result
Request operation
Return result
Application server
Wait for data
Request data
Return data
Database server
Time

- Server may act as a client
  - Example would be transaction monitor across multiple databases



Modern Architectures: Horizontal

Front end handling incoming requests
Replicated Web servers each containing the same Web pages
Requests handled in round-robin fashion
Disks
Internet

- Rather than vertical, distribute servers across nodes
  - Example of Web server "farm" for load balancing
  - Clients, too (peer-to-peer systems)