Distributed Systems - Architecture

CS239
Advanced Operating Systems
April 7, 1997
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Lecture Source Materials

Singhal, **Chapter 4: Architectures of Distributed Systems**

Tanenbaum, <u>Distributed OS</u>, Chapter 1-2.

Goscinski, <u>Distributed OS</u>, Chapter 1-3

Outline

- Definition: What is a distributed system?
- Motivation: Why do we care?
- Taxonomy: Is it a NOS? a DOS? a MOS?
- Design Issues: What are the fun problems?
- Communications: How to organize things?
- Communications: How to talk?

What is a distributed system?

Assorted definitions:

"a term used to define a wide range of computer systems, from weakly-coupled systems such as wide area networks to strongly-coupled systems such as local area networks to very strongly-coupled systems such as multiprocessor systems." (Goscinski, p. 3)

more...

" ... consists of several computers that do not share a memory or clock; the computers communicate with each other by exchanging messages over a communications network; and each computer has its own memory and runs its own operating system." (Singhal, p. 71)

and...

"a collection of independent computers that appear to the users of the system as a single computer." (Tanenbaum, p. 2)

- Key point: **AUTONOMY**

Examples

- CSD workstation network
- Robotic factory
- Bank branches

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Motivation for Dist. Systems

- Performance Economics + Communications
  – Grosch' s Law (MIPS : $ * $)
  + Moore's Law (density = 2^(t - 1962))
- Inherently distributed tasks
+ Increased reliability
+ Incremental expandability
+ Resource sharing

and the downside...

– Software complexity
– Network reliability
– Security
– Supply/Demand location mismatch
– Non-decomposable computation

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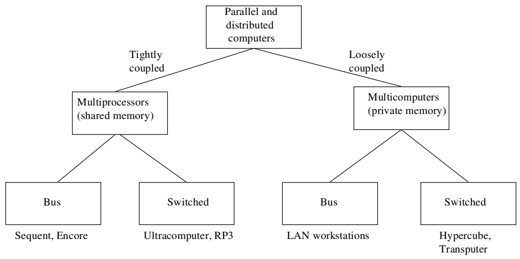
Distributed System Taxonomy

- Hardware
  – Flynn's SISD/SIMD/MISD/MIMD
  – Tanenbaum's MIMD taxonomy

Tanenbaum MIMD Taxonomy



Software Taxonomy

- Tightly vs loosely coupled
- Crossproduct of coupling and HW/SW

		HARDWARE	
		loosely coupled	tightly coupled
SOFTWARE	loosely coupled		
	tightly coupled		

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	tightly coupled	Distributed Operating System (DOS)	

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SOFTWARE	loosely coupled	Network Operating System (NOS)	
	tightly coupled	Distributed Operating System (DOS)	Multiprocessor Timesharing (MOS)

Software Taxonomy

Item	NOS	DOS	MOS
Appear to be virtual uniprocessor?	No	Yes	Yes
All CPUs run same OS?	No	Yes	Yes
How many OS copies?	n	n	1
How is communication achieved?	Shared files	Messages	Shared memory
A priori network protocols agreement?	Yes	Yes	No
Single run queue for processes?	No	No	Yes
Well-defined semantics for file sharing?	Usually No	Yes	Yes

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Distributed OS Design Issues

- Transparency
- Flexibility: mono- vs. μ-kernel
- Reliability
- Performance
- Scalability
- Process Synchronization
- Compatibility
- Resource Management

Transparency: Single-system image

- Location transparency
- Migration transparency
- Replication transparency
- Concurrency transparency
- Parallelism transparency

Reliability

- Availability
- Integrity
  - storage: correct, consistent
  - computation
  - security
- Fault Tolerance
  - Richer failure modes
  - client-server model

Performance

- fine- vs. coarse-grained parallelism
- metrics
- measurement methods/tools

Scalability

- avoid centralized
  - components
  - tables
  - algorithms
    - no machine has complete info about system state
    - machines make desicions only on local info
    - failure of one machine doesn't ruin whole algorithm
    - no implicit assumption of global clock

Compatibility

- Binary
- Execution
- Protocol

Resource management

- Data migration
- Computation migration
- Distributed scheduling
- Security

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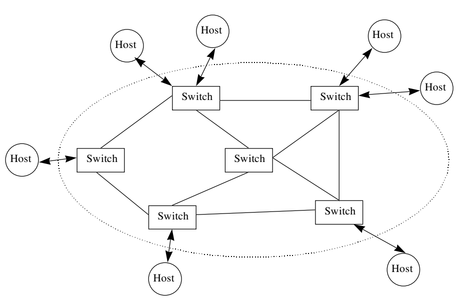
Communications Networks

- Wide area networks (WANs)
- Local area networks (LANs)
- ISO OSI reference model

Wide area networks (WANs)



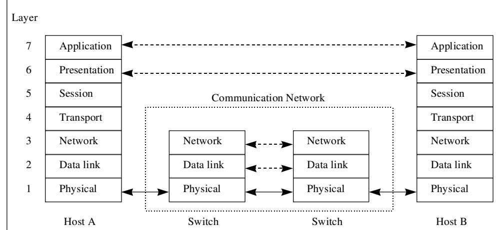
Wide area networks (WANs)

- Links are leased circuits from telcos
  - Arpanet was 56Kbps
  - Internet backbone today is T3 (45Mbs)
    - typical link is T1 (1.5Mbps)
    - new backbone at 1Gbs (ATM SONET)
    - typical ATM link is 155Mbps
- Heterogeneous hosts
- Circuit vs Packet switching
  - Store-and-forward

Local area Networks (LANs)

- 10Mbps-100Mbps transmission rate
- Small geographic scope (<10km)
- Topologies
  - Bus/tree: CSMA/CD, token bus
  - Ring: token ring, slotted ring
- Low transmission error rate

ISO OSI Reference model



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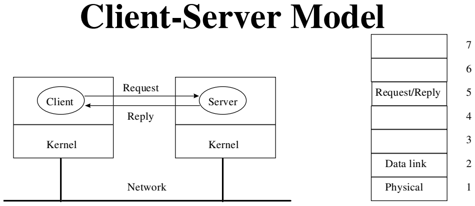
Communications Primitives

- Client-Server Model
- Remote Procedure Call
- Group Communication

Client-Server Model



- Request/reply message passing protocol
- Blocking vs. non-blocking primitives
- Buffered vs. unbuffered primitives
- Reliable vs. unreliable primitives

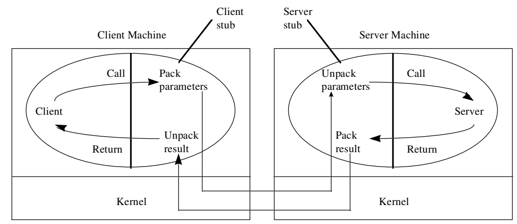
Message passing problems

- Pairing replies with requests
- Heterogeneous data representation
- Addressing remote partner
- Handling system/communication failures

Remote Procedure Call

- Basic RPC model
- Detailed RPC issues

Basic RPC Model



RPC details

- Client/server stubs
- Dynamic binding to server
- Parameter/result marshaling
- Failure semantics

Parameter/result marshaling

- Call-by-value/reference/…
- Heterogeneous hardware architectures
  – ASCII vs EBCDIC
  – big vs little endian
  – strings vs integers
- Canonical form vs dynamic conversion
- Pointer dereferencing

Failure semantics

- Lost replies & idempotency
- Client crash & orphans
- Server crash
  – At least once semantics
  – Exactly once semantics
  – At most once semantics
  – No promises semantics

Group Communication

- Basics
- Group management
- Correctness Issues

Basics of Group Communication

- one-to-one vs. one-to-many
- dynamic groups
- multicast/broadcast/unicast

Group Management

- closed vs. open groups (exclusivity)
- peer vs. hierarchical (internal)
- group membership (dynamic mgt)
- group addressing (single/multiple/predicate)

Correctness of Group Communication

- Send/Receive primitives (merge RPC/group?)
- Atomicity
- Message ordering (global/consistent time)
- Overlapping groups
- Scalability (volume/gateway)

Summary

- Definition: A distributed system is …
- Motivation: We care because ...
- Taxonomy: An OS is an xOS because ...
- Design Issues: The fun problems are ...
- Communications: We organize things ...
- Communications: Pieces talk by ...