
Distributed Systems (COMP9243)

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Ihor Kuz
cs9243@cse.unsw.edu.au

DISTRIBUTED SYSTEMS (COMP9243)

Lecture 1: Introduction

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- ① Distributed Systems - what and why
 - ② Architecture (Hardware and Software)
 - ③ Challenges
 - ④ Overview - principles and paradigms
 - ⑤ Course details
 - ⑥ Erlang
-

DISTRIBUTED SYSTEMS

What is a *distributed system*?

→ Andrew Tannenbaum defines it as follows:

A distributed system is a collection of independent computers that appear to its users as a single coherent system.

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→ Is there any such system? **Hardly!**

→ We will learn about the challenges in building “true” distributed systems

For the time being, we go by a weaker definition of distributed system:

A distributed system is a collection of independent computers that are used jointly to perform a single task or to provide a single service.

Examples of distributed systems

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- Collection of Web servers: distributed database of hypertext and multimedia documents
 - Distributed file system on a LAN
 - Domain Name Service (DNS)
 - Cray XT5 & CLE (massive multiprocessor)
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Find more examples of distributed systems:

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Remember

A distributed system is a collection of independent computers that are used jointly to perform a single task or to provide a single service.

THE ADVANTAGES OF DISTRIBUTED SYSTEMS

What are economic and technical reasons for having distributed systems?

Cost. Better price/performance as long as commodity hardware is used for the component computers

Performance. By using the combined processing and storage capacity of many nodes, performance levels can be reached that are out of the scope of centralised machines

Scalability. Resources such as processing and storage capacity can be increased incrementally

Reliability. By having redundant components, the impact of hardware and software faults on users can be reduced

Inherent distribution. Some applications like the Web are naturally distributed

THE DISADVANTAGES OF DISTRIBUTED SYSTEMS

What problems are there in the use and development of distributed systems?

New component: network. Networks are needed to connect independent nodes, are subject to performance limits, and constitute another potential point of failure

Security. It is easier to compromise distributed systems

Software complexity. Distributed software is more complex and harder to develop than conventional software; hence, it is more expensive and harder to get right

Distributed systems are hard to build and understand
➔ this course is going to be very challenging!

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DISTRIBUTED SYSTEM ARCHITECTURE

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Hardware Architecture:

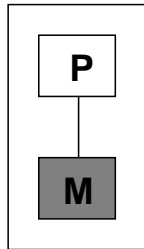
- Uniprocessor
- Multiprocessor
- Multicomputer

Software Architecture:

- Uniprocessor OS
 - Multiprocessor OS
 - Network OS (NOS)
 - Distributed OS (DOS)
 - Middleware
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HARDWARE ARCHITECTURE

Uniprocessor:

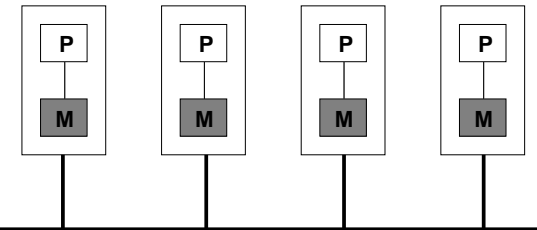


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Properties:

- Single processor
- Direct memory access

Multicomputer:

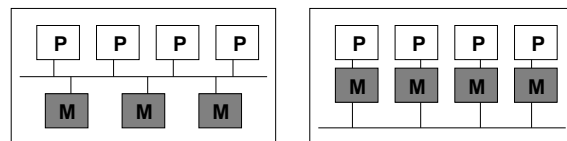


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Properties:

- Multiple computers
- *No direct memory access*
- Network
- Homogeneous vs. Heterogeneous

Multiprocessor:



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Uniform

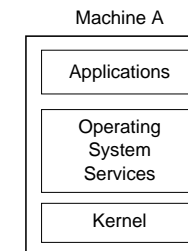
Nonuniform

Properties:

- Multiple processors
- Direct memory access
- Uniform memory access (e.g., SMP, multicore)
- Nonuniform memory access (e.g., NUMA)

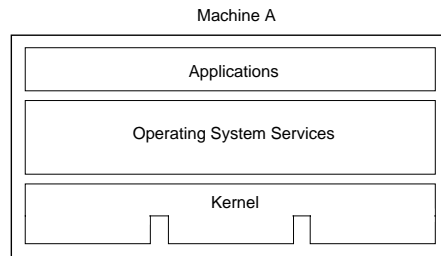
SOFTWARE ARCHITECTURE

Uniprocessor OS:



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Multiprocessor OS:

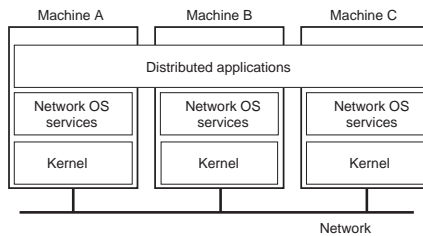


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Similar to a uniprocessor OS but:

- Kernel designed to handle multiple CPUs
- Number of CPUs is transparent
- Communication uses same primitives as uniprocessor OS
- Single system image

Network OS:

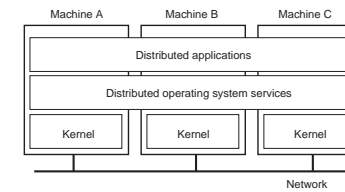


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Properties:

- No single system image
- Individual nodes are highly autonomous
- All distribution of tasks is explicit to the user
- Examples: Linux, Windows

Distributed OS:



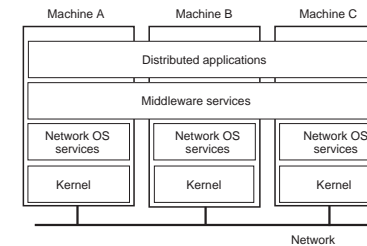
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Properties:

- High degree of transparency
- Single system image (FS, process, devices, etc.)
- Homogeneous hardware
- Examples: Amoeba, Plan 9, Chorus, Mungi

Are there any problems with this approach?

Middleware:



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Properties:

- System independent interface for distributed programming
- Improves transparency (e.g., hides heterogeneity)
- Provides services (e.g., naming service, transactions, etc.)
- Provides programming model (e.g., distributed objects)

Why is Middleware 'Winning'?:

- Builds on commonly available abstractions of network OSes (processes and message passing)
- Examples: RPC, NFS, CORBA, DCOM, J2EE, .NET
- Also languages (or language modifications) specially designed for distributed computing (e.g., Erlang, Ada, Limbo, etc.)
 - ✓ Usually runs in user space
 - ✓ Raises level of abstraction for programming → less error-prone
 - ✓ Independence from OS, network protocol, programming language, etc. → Flexibility
 - ✗ Feature dump and bloated interfaces

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DISTRIBUTED SYSTEMS AND PARALLEL COMPUTING

- Parallel computing: improve performance by using multiple processors per application
- There are two flavours:
 1. Shared-memory systems:
 - Multiprocessor (multiple processors share a single bus and memory unit)
 - SMP support in OS
 - Much simpler than distributed systems
 - Limited scalability
 2. Distributed memory systems:
 - Multicomputer (multiple nodes connected via a network)
 - These are a form of distributed systems
 - Share many of the challenges discussed here
 - Better scalability & cheaper

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DISTRIBUTED SYSTEMS IN CONTEXT

Networking:

- Network protocols, routing protocols, etc.
- Distributed Systems: **make use of networks**

Operating Systems:

- Resource management for single systems
- Distributed Systems: **management of distributed resources**

This Course:

- Generalised solutions to distributed systems problems and challenges
- Infrastructure software to help build distributed applications

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BASIC PROBLEMS AND CHALLENGES IN DISTRIBUTED SYSTEMS

The distributed nature of a systems gives rise to the following challenges:

- Transparency
- Scalability
- Dependability
- Performance
- Flexibility

This course will examine approaches and techniques for designing and building distributed systems that address these challenges.

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TRANSPARENCY

Concealment of the separation of the components of a distributed system (single image view).

There are a number of forms of transparency

Access: Local and remote resources accessed in same way

Slide 21 Location: Users unaware of location of resources

Migration: Resources can migrate without name change

Replication: Users unaware of existence of multiple copies

Failure: Users unaware of the failure of individual components

Concurrency: Users unaware of sharing resources with others

Is transparency always desirable? Is it always possible?

SCALABILITY

A system is said to be scalable if it can handle the addition of users and resources without suffering a noticeable loss of performance or increase in administrative complexity

(B. Clifford Neuman)

Scale has three dimensions:

Slide 22 Size: number of users and resources (problem: overloading)

Geography: distance between users and resources (problem: communication)

Administration: number of organisations that exert administrative control over parts of the system (problem: administrative mess)

Note:

- Scalability often conflicts with (small system) performance
 - Claim of scalability is often abused
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Techniques for scaling:

- Decentralisation
- Hiding communication latencies (asynchronous communication, reduce communication)
- Distribution (spreading data and control around)
- Replication (making copies of data and processes)

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Decentralisation

Avoid centralising:

- Services (e.g., single server)
- Data (e.g., central directories)
- Algorithms (e.g., based on complete information).

Slide 24 With regards to algorithms:

- Do not require machine to hold complete system state *Why?*
- Allow nodes to make decisions based on local info *Why?*
- Algorithms must survive failure of nodes
- No assumption of a global clock

Decentralisation is *hard*

DEPENDABILITY

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- Dependability of distributed systems is a double-edged sword:
 - Distributed systems promise higher **availability**:
 - Replication
 - But **availability may degrade**:
 - More components → more potential points of failure
- Dependability requires consistency, security, and fault tolerance

PERFORMANCE

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- Any system should strive for maximum performance
- In distributed systems, performance directly conflicts with some other desirable properties
 - Transparency
 - Security
 - Dependability
 - Scalability

How?

FLEXIBILITY

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- Build a system out of (only) required components
- Extensibility: Components/services can be changed or added
- Openness of interfaces and specification
 - allows reimplementing and extension
- Interoperability
- Separation of policy and mechanism
 - standardised internal interfaces

COMMON MISTAKES

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False assumptions commonly made:

- ① Reliable network
 - ② Secure network
 - ③ Everything is homogeneous
 - ④ Topology does not change
 - ⑤ Zero latency
 - ⑥ Infinite bandwidth
 - ⑦ Zero transport cost
 - ⑧ One administrator
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PRINCIPLES

Several key principles underlying all distributed systems

- System Architecture
- Communication
- Replication and Consistency
- Synchronisation
- Naming
- Fault Tolerance
- Security

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Discussion of these principles will form the core content of the course

PARADIGMS

Most distributed systems are built based on a particular paradigm (or model)

- Shared memory
- Distributed objects
- Distributed file system
- Shared documents
- Distributed coordination
- Agents

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This course will cover the first three in detail.

MISCELLANEOUS 'RULES OF THUMB'

Trade-offs Many of the challenges provide conflicting requirements. For example better scalability can cause worse overall performance. Have to make trade-offs - what is more important?

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Separation of Concerns Split a problem into individual concerns and address each separately

End-to-End Argument Some communication functions can only be reliably implemented at the application level

Policy vs. Mechanism A system should build mechanisms that allow flexible application of policies. Avoid built-in policies.

Keep It Simple, Stupid make things as simple as possible, *but no simpler*.

READING LIST

End-to-end Arguments in System Design A classic paper arguing the end-to-end argument with excellent examples.

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A Note on Distributed Computing Another classic paper showing the dangers of too much transparency in RPC-based distributed systems.

Scale in Distributed Systems A really good paper to read if you are interested in understanding more about scalability in distributed systems.

Fallacies of Distributed Computing Explained A good explanation of the 8 common mistakes made by architects and designers of distributed systems.

OVERVIEW OF COURSE

- ① Introduction and Erlang
- ② System Architecture and Communication
- ③ Replication and Consistency, Distributed Shared Memory
- ④ Middleware, Distributed Objects, Publish/Subscribe, SOA
- ⑤ Synchronisation and Coordination
- ⑥ Dependability and Fault Tolerance
- ⑦ Security
- ⑧ Naming
- ⑨ Distributed File Systems

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Extras:

- ① Parallel Programming
 - ② Clusters and Cloud Computing
 - ③ Distributed Systems in Practice
 - ④ Research and Other Topics
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PRACTICAL COURSE DETAILS

- Course Outline Page
<http://www.cse.unsw.edu.au/~cs9243/outline.html>
- Exercises: Familiarisation, experiment with DS programming
- Assignments: 2 assignments. 50 marks each
- Exam: Open book exam, 100 marks
- Final Mark:
 - weighted average: exam mark (65%) and total assignment mark (35%).
 - Exam mark must be at least 50% of maximum possible exam mark.

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Note:

Difficult course. Lots of work. Be prepared.
And start the assignments on time!
