Distributed Systems

Operating System Issues

Rik Sarkar
James Cheney

University of Edinburgh
Spring 2014
Operating System

• How different operating system issues relate to distributed system design
Operating System

• What is an operating system?
• An operating system is a resource manager
• It provides an abstract computing interface to processes
  – A program (and the programmer) does not need to know the details of the hardware
  – It asks the operating system to have some =thing done, the OS gets it done by the hardware
  – Eg. You don’t need to know what modem or LAN card is being used to write a network based program
    • Ask the OS “please send message m to IP address x”
    • OS has “drivers” for the network interface to get the job done
Operating System

• What is an operating system?
• An operating system is a resource manager
• It provides an abstract computing interface to processes
• OS arbitrates resource usage between processes
  – CPU
  – Memory, filesystem
  – Network
  – Keyboard, mouse, monitor
  – Other hardware
• This makes it possible to have multiple processes in the same system
  – If 2 processes ask for use of same resource
  – OS decides who gets is when, how much etc
Operating System

- How OS handles different resources
- Memory:
  - Each process is given a different part of memory to use, they cannot access other’s memory
  - If it needs more memory, OS will allocate from unallocated memory store
- Filesystem
  - OS checks that process has rights to read/write the file
  - Makes sure that 2 processes are not writing the same file
- Network:
  - OS receives messages from processes, sends them to network card one at a time
  - When messages are received, OS delivers to suitable processes
Operating System

• How OS handles different resources
  • Keyboard/mouse:
    – User types/clicks. Which application should get it?
    – OS decides
  • Apps want to display things on screen.
    – OS decides when/where display will occur
  • CPU: the most basic resource
    – Each process runs for a short period, and the control returns to OS
    – OS selects the process to run for the next slice
Operating System

• Hardware is designed so that OS can enforce these actions. E.g.:
• CPU has kernel mode and user mode
  – Certain commands can only be used in kernel mode
• Memory:
  – Process X thinks it is using memory from 0000 to 1000
  – Actually, it is using 40050000 to 40051000
  – The 4005 is loaded into first part of the memory address register when the process starts executing
  – Process has no way to know or modify it
Operating System

• OS makes processes *oblivious* of environment
• Process does not know details of hardware
• Process does not know about other processes (unless they communicate with each-other)
Threads

• Threads are processes inside a process!
• They have access to the same memory space
• So communication between threads is easier
• Threads need more or less the same information as the process itself, so switching execution between threads is less work for the OS
  – Lightweight context switch
Threads

• Use of threads:
  – Imagine a server interacting with many clients
  – A separate thread per client makes it easier to write a program that works with many clients
  – Suppose client 1 is slow, and client 2 works faster
  – When thread 1 is waiting for client 1 to respond, thread 2 can continue working for client 2
Networked OS (any standard OS)

• A networked OS is aware that it is connected to the network
• Every node has an OS running
• Every node manages the resources at that node
• A process can request communication to processes in other nodes
  – It has to be explicitly aware that it is requesting service at at different node
  – And which node it is requesting (eg. I.P. address)
  – So it also has to know which services/resources are available in the network
• A process cannot request resources in control of a different computer
• It has to communicate with a process on that computer and request it to do the job
• Distributed computing has to be done explicitly
Distributed OS

• The OSes running on the different computers act like a single OS
• A process does not get to know (or need to know) that other resources/processes are at other computers
• E.g.:
  – Process gets input/output from hardware X, which can be on any computer
  – Process A communicates with process B the same way whether they are on same computer or not
  – OS takes care of using the network if needed
• A process may be running on a different computer from where it was started. Processes can be moved among different computers
• The “distributed” nature of the system is hidden from the processes
• The OS manages all the “distributed” aspects
Distributed OS

• One interface to all resources in the network

• Regular program can be made to run in a distributed fashion

• Easier to program applications that make use of networked resources

• Or is it?
Problems with distributed OS

- What happens if part of the network fails, and processes are separated into 2 sets?
  - Now we have to tell processes that the network has failed, and process has to take action
  - What if some OS-processes were moved elsewhere?
- Suppose we start processes A and B on the same computer
  - OS moves them to different computers
  - But A and B communicate a lot, so it would have been efficient to have them on the same computer!
Problems with distributed OS

• Access to offsite resources
  – Has to be through explicit network connection
  – All computers in the world cannot be in same system!

• Adding new nodes to a distributed computing
  – May be part of a different instance of the OS
  – We will still need explicit connections

• Distributed OS does not help a lot with distributed computing
Problems with distributed OS

• A network/computer failure means part of the OS failed
  – Very hard to design an OS that can handle such failures
• Distributed OS has to allow for lots of different possibilities in distributed computing
  – Harder to design
  – In fact, it is not possible to allow for all different possibilities
• “Distributed computing” means different things in different cases
• Better to let the application programmer decide how it will be distributed, and how to handle communication, failure etc
• OS provides only the basic infrastructure
Networked OS vs Distributed OS

- As a result, we do not have any distributed OS in regular use
- Networked OS are popular
- Provide communication facilities
- Let software decide how they want to execute distributed computation
  - More flexibility
  - Failure etc are application’s responsibility
  - OS continues to do basic tasks
Virtualization

- A virtual machine runs as an application on a computer
- It *emulates* the hardware of a computer
- It is possible to run an operating in a virtual machine
  - The VM application takes the OS executable as input
  - It then meticulously executes the steps a real computer would have taken
  - But does this in a virtual environment
  - That is, instead of a real CPU, the VM has a data structure representing a CPU
  - It then modifies the variables in the data structure exactly the way the registers of a CPU would have changed when executing those instructions
  - Same with memory, hard drive, network card etc
Virtualization

• When an application is run inside the “guest” OS running in the VM, the VM emulates the process of the OS as well as the application.
Virtualization

• Useful for sandboxing, testing, backup
• Suppose you have a new OS to test
• Or trying to add a new component to the OS, such as a new device driver
• Running on actual hardware and having it crash is a lot of hassle to manage, reboot etc
• VM gives a nice way to test
• Also, you don’t have to waste an entire machine just because you are playing with the OS!
Virtualization

- VM gives a nice way to test
- Easy to modify the executable code and run again
- Since everything is just variables in the VM’s memory, the VM can write all this to a file, which can be used to debug and find exactly what happened
- In general, VMs can store “snapshots” for analysis and backup
Virtualization

- VM gives a nice way to test
- Easy to modify the executable code and run again
- Since everything is just variables in the VM’s memory, the VM can write all this to a file, which can be used to debug and find exactly what happened
- In general, VMs can store “snapshots” for analysis and backup
Virtualization and distributed computing

• Consider a server farm
• Many different servers are running
• Instead of giving a physical server to each, many server farms consist of real servers running virtual machines
• For example, renting a server to host a web site is likely to give you a VM based server
Virtualization and distributed computing

• Advantages: more flexibility
  – Multiple VMs on same computer
    • Need fewer physical machines
  – Easier to turn on/off
  – Easier to backup
  – VMs can be moved from one computer to another while preserving state
    • Useful when the work load changes, some servers need more computation, others need less.
Virtualization and distributed computing

• This is *not* a good strategy for CPU intensive computation such a large data mining
• Because running a large computation in a virtual machine is inefficient
• However, many systems need computation running all the time, but not so intensively
• Virtualization is most useful when flexibility is critical
Virtualization

• Server farms and clusters
• Cloud computing
• Dynamic resource usage
• Testing
Virtualization and distributed computing

- Hardware -> OS -> VMapp -> VOS ->
- Vapp -> thread
Virtualization at the heart of computing

A computer is a Turing machine
- There is a controlling state machine (the hardware circuit)
- There is a tape with info (memory and files)
- A “head” that can access different locations on tape
- The data at the current head location is input
- Input + state => output (written) + move the head
- Any computing system can be described as a Turing machine

Distributed Systems, Edinburgh, 2014
Virtualization at the heart of computing

A program is a Turing machine
- There is a controlling state machine (the executable code)
- There is a tape with info (the data in the memory/variables)
- A “head” that can access different locations on tape
- The data at the current head location is input
- Input + state => output (written) + move the head
- Any software can be described as a Turing machine!
Virtualization at the heart of computing

Computer is a Universal Turing machine

• It simulates the actions of other Turing machines (programs)
Some current trends in OS

• Mobile OS
  – Heavily contested area
  – Adaptation to mobility
  – Harder to network when moving
  – Adaptation to low energy system
  – Different style of user interaction
  – Needs better synchronization across multiple mobile user devices
Some current trends in OS

• Sensor OS
  – For sensor networks
  – TinyOS, LiteOS, Contiki
  – Small, low power sensor devices
  – Needs efficient operation
  – Needs specialization to process and handle sensor data and related operations in place of application interface
Some current trends in OS

• Embedded OS
  – Computers all around us, in every device/machine
  – Needs OS
  – Distributed computing, since they need to communicate with each-other
  – Adaptation to low power, low resource environment
  – Has to run without supervision/interaction
Summary

• Leader election
• Multicast
• Agreement
• Termination Detection
• P2P
  – Properties, examples
• OS in distributed systems
• Virtualization